FIELD OVERSIGHT PLAN
GW/SW OPERABLE UNIT:
FIELD PILOT TESTING
Galena Subsite
Cherokee County Site
Issued: May 21,1989(Preliminary)

INTRODUCTION

This oversight activity is authorized under EPA Work Assignment 223-7L37. The activities being oversighted are described in a Work Plan dated April 1989. The procedures to be followed by the PRP Group has been outlined in transmittals to EPA and consist of revisions to previously issued EPA documents including the QAPP and FOP for the Galena Subsite.

ACTIVITIES BEING OVERSIGHTED

The following activities are planned to be performed by the PRP Group consultant during the period starting on or about May 22, 1989. The following is a summary of the activities anticipated to be performed during this period.

- collection, characterization, and stockpiling of mine waste rock and chat in the 8 EPA mine waste zones
- collection and characterization of waters in selected mine shafts and subsidences in the 8 EPA mine waste zones
- conducting classification and sorting of the mine waste rock and chat in the stockpiles
- conducting batch leach tests with combinations of mine waste rock, chat and on-site groundwater
- conducting of flow-through leach tests with combinations of mine waste rock, chat and on-site groundwater (procedures not specified at this time)

The EPA may chose not to provide oversight for all of the for all the listed activities. The actual schedule for conducting the field and leach tests may vary. The testing is anticipated to be completed by the middle of June 1989.

ROLE OF OVERSIGHT PERSONNEL AND LINES OF COMMUNICATION

CH2M HILL's role during the course of field oversight activities will be to monitor the PRP fieldwork as specified in this document and any issued addenda. The basic functions of the oversight personnel are the following:

1. Document procedures (field log and photos) used by the PRP group during the conduct of the work described in the work plan. The log shall be summarized daily.

2. Report activities daily to CH2M Hill project manager or EPA.

3. Provide XRF instrument and operator for use in determining the metals contents of field samples. These results will be shared with the PRP group as they become available.

4. Collect quality control samples or sample splits or replicates as outlines in the work plan.

5. Consult appropriate Region VII or CH2M Hill staff regarding situations that arise during the oversight that require action.

6. All duties will be performed in a professional, responsible, and nonconfrontational manner.

The following activities are not within the role of the field oversight staff.

1. The field oversight staff is not empowered to authorize changes to the approved work plan.

2. The field oversight staff will not undertake any responsibilities of the PRP staff, consultants, or contractor.

3. The field oversight staff will not be responsible for obtaining access to any property.

END

7-2

Gale / Jane K

Find attached key excerpts from the PRP's "Pilot Test Report." The full report is available upon request. The attached excerpts provide you key data, conclusions and recommendations made by ABC-Mark Logsdon on behalf of the PRP's.

* Bottom line - it appears, at this time, that the pilot test results support our new alternative (No. 5 in our Supplement) to selectively place wastes below ground.

⟹ Please comment / discuss at your earliest convenience.

NOTE: A PRP meeting is tentatively scheduled for ~ July 18 to discuss above and proposed plan.

Jane - Do we need to send (Special) Notice letters out to the PRPs in the near future. The plan as I understand was to "Notice" the PRPs once we knew our preferred remedy. The OUTS Supplement was to accompany the letters.

⟹ Please comment / discuss

DRAFT
REPORT TO
CHEROKEE COUNTY SITE
PARTICIPATING PRPs

PILOT LEACH TESTING
GALENA SUBSITE, KANSAS

Prepared for

CHEROKEE COUNTY CERCLA SITE PARTICIPATING PRPs:

AMAX Mineral Resources
ASARCO
Gold Fields American
NL Industries
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by

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June, 1989

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June 30, 1989 Ref: 1091C/890630

US EPA, Region VII
726 Minnesota Avenue
Kansas City, Kansas 66101

VIA FEDERAL EXPRESS

Attn: **Mr. Glen Curtis**

Re: **DRAFT REPORT OF INVESTIGATIONS: PILOT LEACH TESTING**

Dear Mr. Curtis:

Attached please find the Draft Report of Investigations, "Pilot Leach Testing - Galena Subsite, Kansas" describing the pilot leach testing program undertaken by the participating PRP group. The report describes the program, presents the data, and evaluates the likely impact of the Additional Alternative in terms of water quality.

The agreement between the Participating PRPs and EPA/VII called for a draft report to be submitted by June 30, 1989. This Draft Report of Investigations, which has been prepared as a contractor report to the Participating PRPs, completes that deliverable. The data for the field program are complete; copies of the original laboratory reports from Bruce Williams Laboratory, Joplin, Missouri are presenetd in Appendix C. The tables and figures in the body of the draft text include all the data that were available to us by 1200h MDT on June 30, 1989. These data include metals and sulfate analyses through pore volume 30, well into Cycle 3. It is very clear that the leachate has returned to steady values well within the baseline range of starting waters, as discussed at length in the text.

The remaining data, which is included in Appendix C, will be included in updated tables as soon as possible. All required data (including all our QC data from the outside laboratory) will be presented in final form in the final report, as agreed to between the Particpating PRPs and EPA/VII. I have reviewed the data from the final pore volumes, and I can see no anomalies in the portions of the data that are not tabulated and graphed in the text of the draft report.

I trust that you will find this letter and the Draft Report of Investigations acceptable. If you have questions about this letter, please contact me or Mr. Paulsen (AMAX). As you know, I will be on holiday from July 1 to July 8. In my absence, you may contact Ms. Barbara Basse, the ABC Project Engineer, who is intimately familiar with the program and this report.

We anticipate being able to reach closure with you and your contractors on the termination of the experiment and the dismantling of the test tanks next week. Per our discussion of last week, I am sending a copy of this report directly to Mr. Geitner at CH2M Hill. I have already spoken with him about discussing termination of the test with Ms. Basse in my absence.

Nothing in this letter is to be construed as altering the terms or conditions of the Professional Services Agreement between Adrian Brown Consultants, Inc. and the Participants (Amax Mineral Resources Company, NL Industries, Gold Fields American Corporation, ASARCO, and Sun Company, Inc.). Because Adrian Brown Consultants is an independent contractor, the firm is not authorized to speak on behalf of the Participants with respect to any matters outside the scope of the current agreement. In particular, no statement by Adrian Brown Consultants or any of its employees or subcontractors may be considered an admission or waiver of any defense by any or all of the PRPs concerning liability for response costs or concerning the propriety of U.S. Environmental Protection Agency's actions at the Cherokee County site as a whole or the Galena subsite in particular.

Sincerely,
ADRIAN BROWN CONSULTANTS, INC.

Mark J. Logsdon

Mark J. Logsdon, Project Manager

cc: K.R. Paulsen (AMAX)
B. Sams (NL)
A. E. Godduhn (Gold Fields American)
J. Richardson (ASARCO)
L. Grossi-Tyson (Sun)

N. Geitner, CH2M Hill

File 1091C
A. Brown (ABC)
A. Smith (ASCI)
G. Upphof (EMS)

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1.0 INTRODUCTION

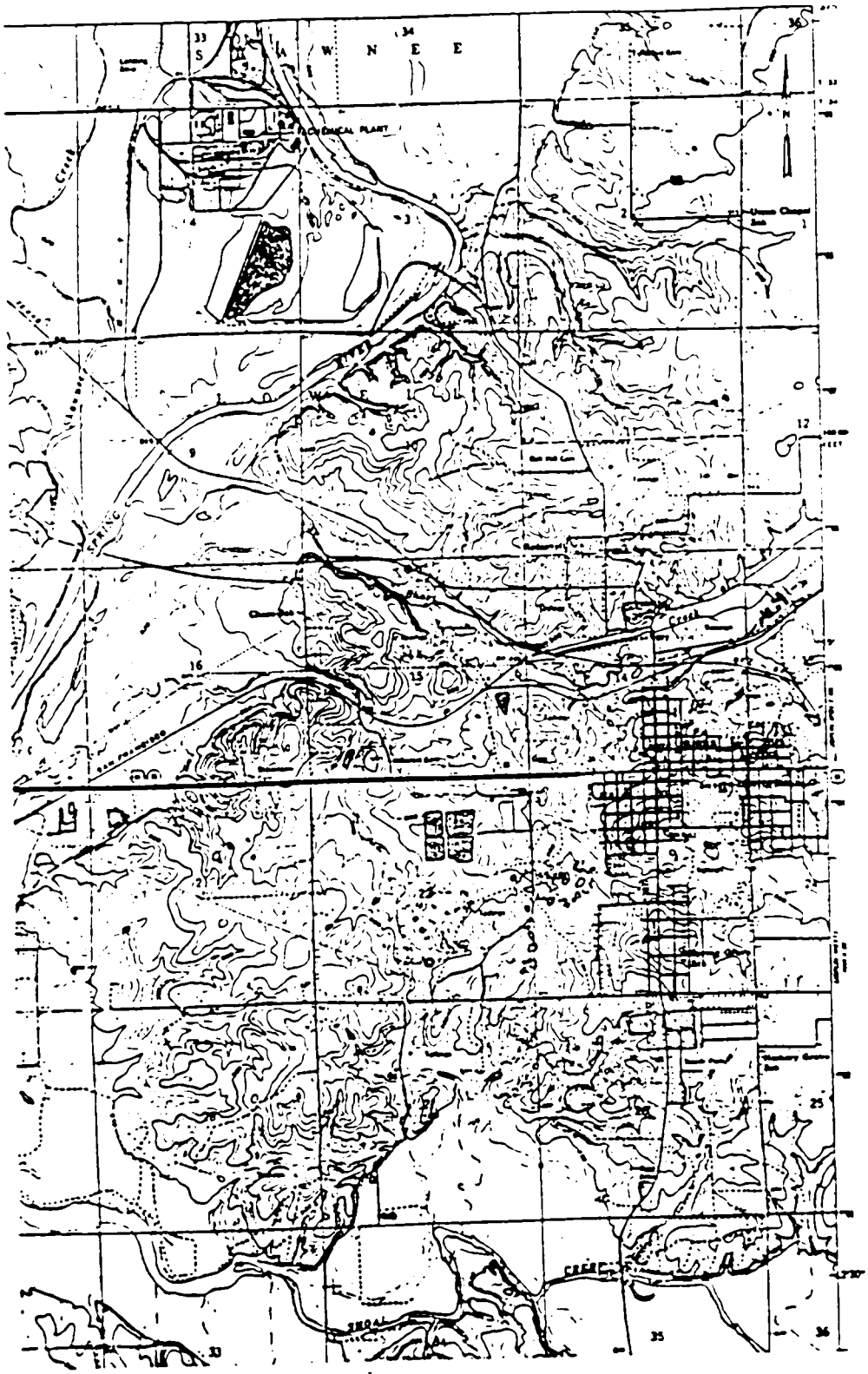
1.1 BACKGROUND

Cherokee County, Kansas, includes the Kansas portion of the Tri-State Mining District, a 500-square-mile area in Oklahoma, Kansas and Missouri that was one of the world's leading lead-zinc mining districts. The 900-acre Galena Subsite is one of six mining areas that comprise the overall Cherokee County CERCLA Site, as designated by the U.S. Environmental Protection Agency.

The Galena Subsite centers around the town of Galena, Kansas, a residential community of 3,588 (1980 census) (Figure 1.1). Mining in the Galena area occurred primarily from the 1880's to the early 1900's, with a small resurgence of activity in the 1940's. Smelting occurred along Short Creek from the 1890's to 1961. The subsite area is underlain by abandoned mines, and there are approximately 1.5 million cubic yards of waste rock and milling residue (chat) on the ground surface. The abandoned mines flooded following the end of ground water pumping.

Over geologic time, oxygenated water has reacted with metallic sulfides in mineralized areas to produce locally acidic water with relatively high concentrations of dissolved metals, including

Figure 1.1 - Plan of the Galena Subsite Area



iron, managanese, cadmium, lead and zinc (Angino, 1988). The ground waters containing metals discharge seasonally to local creeks, primarily Short Creek.

In 1984, the U.S. Environmental Protection Agency (EPA) prepared a Remedial Action Master Plan for the Cherokee County Site, reviewing the site issues and proposing a scope of work for Remedial Investigation and Feasibility Study activities. Phase I Remedial Investigations for the Galena subsite were completed by EPA in 1986. Work by EPA, primarily in 1987 and 1988, led EPA to propose a remedy (currently called the Preferred Alternative) that, in addition to some remediation of surface water drainage and of potential cross contamination of the deep aquifer due to boreholes or failed well casings, proposed conventional milling of waste materials at the site followed by disposal of milled tailings into mine voids.

In late 1988, the Cherokee County potentially responsible parties (PRPs) performed a laboratory investigation of the leachability of waste rock and chat under fully and variably saturated conditions for the purpose of evaluating likely effects on water quality of disposing of untreated waste rock and chat to the mine voids in the Galena subsite area (ABC, 1988a). The PRP study showed that, for the test conditions (which included crushing the waste materials prior to leaching), the waste materials under fully saturated conditions did not leach significant amounts of metals or generate additional acid drainage after a very short, initial

leaching that probably is associated with the grinding that was required by the EPA experimental protocol. The variably saturated experiments showed a slightly higher tendency to leach metals from the crushed waste materials, though the test results were not significantly different for the untreated waste materials than they were for tailing prepared by the EPA bench-scale methodology. The PRP study concluded that if any remedial action is needed at all, both empirical data from these tests (and other laboratory and field tests around the world) and theoretical geochemical considerations suggested that disposal of untreated waste materials below the water table would likely limit the dissolution reactions that cause metals to leach and mitigate the potential for water quality degradation (ABC, 1988a).

1.2 RESPONSE AND ADDITIONAL DIRECTION FROM THE U.S. EPA, APRIL, 1989.

By letter from A. Feurst (EPA/VII) to P. Keppler (AMAX), the EPA invited the PRPs to a meeting in Kansas City, Kansas to discuss the status of the Agency's reevaluation of the Preferred Alternative (conventional milling) in light of additional metallurgical results and the PRPs' laboratory investigation of 1988.

In the April 10, 1989 meeting, EPA and their contractors presented the results of their metallurgical testing, showing that even with

a very elaborate crushing and five-stage flotation process, extraction of metals from the waste rock was incomplete. The EPA's bench-scale process left a fine-grained (minus 200 mesh) tailing that was subject to substantial leaching of metals because of its high area-to-volume ratio and the relatively high residual metal content of the tailing (ABC, 1988a). In addition, based on the revised estimates of the volume of waste material at the subsite provided to EPA by the PRPs (Andes, 1988 a,b), the milling process proposed by EPA likely would lead to costs that were much greater than the apparent benefits of metals reduction available through the Preferred Alternative.

The EPA and its contractors acknowledged that the results of the PRP laboratory-scale testing program (ABC, 1988a) were sufficiently technically supportive of the hypothesis that little or no long-term water quality impacts were to be expected that the matter of disposal without treatment should be pursued as an additional alternative in the Feasibility Study process. CH2M Hill raised several concerns about scaling the laboratory results to full-scale field conditions, particularly when the lixiviant would be actual ground water rather than the artificial rainwater that was specified in the August, 1988 EPA workplan for use in the PRP laboratory program.

CH2M Hill proposed a modification to the so-called Additional Alternative proposed by the PRPs on December, 1988 (ABC, 1988b). In the CH2M Hill proposal for an Additional Alternative,

coarse-grained (i.e., larger than two inches in effective diameter) waste rock and low-zinc chat would be disposed of below the water table, to limit disposal below the water table to materials that are least likely to contribute soluble metals to the ground water. Higher zinc chat and finer grained waste rock would be disposed of above the water table (as these materials are expected by CH2M Hill to be relatively more reactive in the local ground waters), and the entire assemblage would be capped with low lead (less than about 1,000 ppm) chat to minimize any potential ingestion and inhalation risks at and near the ground surface. The CH2M Hill proposal apparently includes additional aspects, particularly related to remediation of surface water conditions, but these were not elaborated in the April, 1989 meeting. The CH2M Hill proposal is now the Additional Alternative under review by the EPA.

As part of the evaluation of the revised Additional Alternative, engineers from CH2M Hill presented and discussed the draft work plan for additional field-scale pilot testing, a copy of which had been sent by EPA along with the letter notifying the PRPs of the April meeting. A copy of the original draft work plan is presented in Appendix A. The purpose of the proposed pilot tests was to evaluate possible water quality impacts using full-sized waste rock and chat and actual Galena-area ground waters in large-scale tests that more closely approach the site conditions that are to be expected if disposal without treatment is pursued.

Following discussion between the PRPs' representatives and the EPA and CH2M Hill, EPA asked the PRPs whether they would undertake the proposed work. Modifications of the draft work plan were proposed by consultants to the PRPs and accepted in principal by both the the EPA and its contractors and the PRPS (Appendix A). Based on the modified work plan, a group of the PRPs (AMAX Mineral Resources; ASARCO; Gold Fields American; NL Industries; and Sun Companies) agreed to undertake the pilot tests and retained Adrian Brown Consultants, Inc. of Denver, Colorado to design and implement the pilot tests and to prepare this report of investigations.

1.3 OBJECTIVES OF THE PILOT LEACH TESTING STUDY

1.3.1 Overall objective

The overall purpose of the pilot leach testing study was to evaluate the effects on ground water quality of disposing of waste rock and chat to mine voids in the Galena subsite area as proposed in the CH2M Hill Additional Alternative, using uncrushed waste rock and low-zinc chat and ground waters from the subsite.

1.3.2 Specific objectives

Specific objectives of the PRP testing program include the following:

1. Material characterization. The first objective was to characterize the materials of interest for the pilot tests with respect to their chemical and physical behavior (i.e., permeability during flow-through leaching) in the Galena subsite environment. Specifically, evaluation of the following matters was made with respect to siliceous and calcareous waste rock, chat, and ground waters in the major subsidence areas of the Galena Subsite:

   a. Material properties. Characterization of the total metal and sulfur content of representative samples of both siliceous and calcareous waste rock and low-zinc chat to be used in the tests. (The permeability of the waste rock and chat mixtures used in the actual tests was determined during the flow-through tests.)

   b. Water chemistry. Characterization of water chemistry from major subsidence ponds in EPA-designated Areas 1, 4, 5, 6, 7, and 8.

2. Estimation of the impacts of the Additional Alternative on groundwater quality. The second objective was to characterize the chemical behavior of the test materials during leaching with local ground water. Specifically, two styles of leaching behavior were evaluated:

   a. Flow-Through Leaching. Evaluation of the rates of leaching by Galena-area groundwaters of coarse-grained waste rock and low-zinc chat and the resulting concentrations of metals of concern under fully saturated leaching conditions as a function of the number of pore volumes of ground water that flow through the materials.

   b. Batch Leaching. In addition, evaluation of maximum likely concentrations, determined through static batch-leaching tests.

1.4 PROJECT TEAM AND RESPONSIBILITIES

The project team, with their general areas of responsibility, includes:

- PROJECT MANAGER - Mark J. Logsdon (Adrian Brown Consultants). Responsible for design and implementation of the pilot test program; for overall project management; for analysis of the geochemistry of the pilot tests; and for preparation of the report of investigations.

- PROJECT ENGINEER - Barbara Basse (Adrian Brown Consultants). Responsible for field characterization and sampling activities; for operation and sampling of the pilot tests; for day-to-day project management in the field; for site safety activities; and for preparing portions of the report of investigations dealing with field methods and procedures, data, and quality assurance.

- FIELD ENGINEER - Gary Andes (Independence Enterprises) Assisted Ms. Basse in field characterization activities and consulted with Adrian Brown Consultants on locations and volumes of waste materials and subsidence features.

- LANDMAN - Howard Sears (Independent consultant, Lebanon, Missouri). Responsible for researching site ownership records and obtaining site access agreements.

- CONSTRUCTION SERVICES - EPIC Construction (Liberty, Missouri) and Tulsa Testing Laboratories (Tulsa, Oklahoma).

- ANALYTICAL SERVICES - PSI-Bruce Williams Laboratory (Joplin, Missouri). Responsible for short-turnaround analyses of metals and other basic chemical parameters; Core Laboratories, Aurora, Colorado. Responsible for quality-assurance analyses and full chemical analyses of selected samples.

- SENIOR TECHNICAL REVIEWERS - Adrian Brown (Adrian Brown Consultants, Inc., Denver, Colorado); Adrian Smith (Adrian

Smith Consulting Inc., Vancouver, BC); Gary Uphoff (Environmental Management Services, Inc., Fort Collins, Colorado).

1.5 ACKNOWLEDGEMENTS

The project team wishes to acknowledge the cooperation of the following individuals and their organizations:

- Ms. Alice Fuerst, Ms. Jane Kloeckner, and Mr. Glen Curtis (U.S. EPA). The EPA Staff promptly reviewed all project materials submitted to them during the course of the pilot test program and provided succinct and timely comments.
- Staff of CH2M Hill. The CH2M Hill staff also promptly reviewed project materials submitted to them during the course of the pilot test program and provided useful comments.
- The Town of Galena. The town clerk and the members of the police and fire departments cooperated at all junctures in providing us access and appropriate levels of security at our test areas.

2.0 PROJECT OVERVIEW

2.1 PROJECT ACTIVITIES

Project activities called for in the EPA direction for this project (EPA, 1989), and subsequently agreed to by the EPA and the PRPs, comprised the following:

1. obtaining access from site owners to collect samples and perform tests on their property;

2. design and preparation of operations plan for field characterization activities;

3. collection of samples of waste rock and chat from the field, and preparation of the samples (sieving and mixing) for chemical analysis of total metals and use in the leach tests;

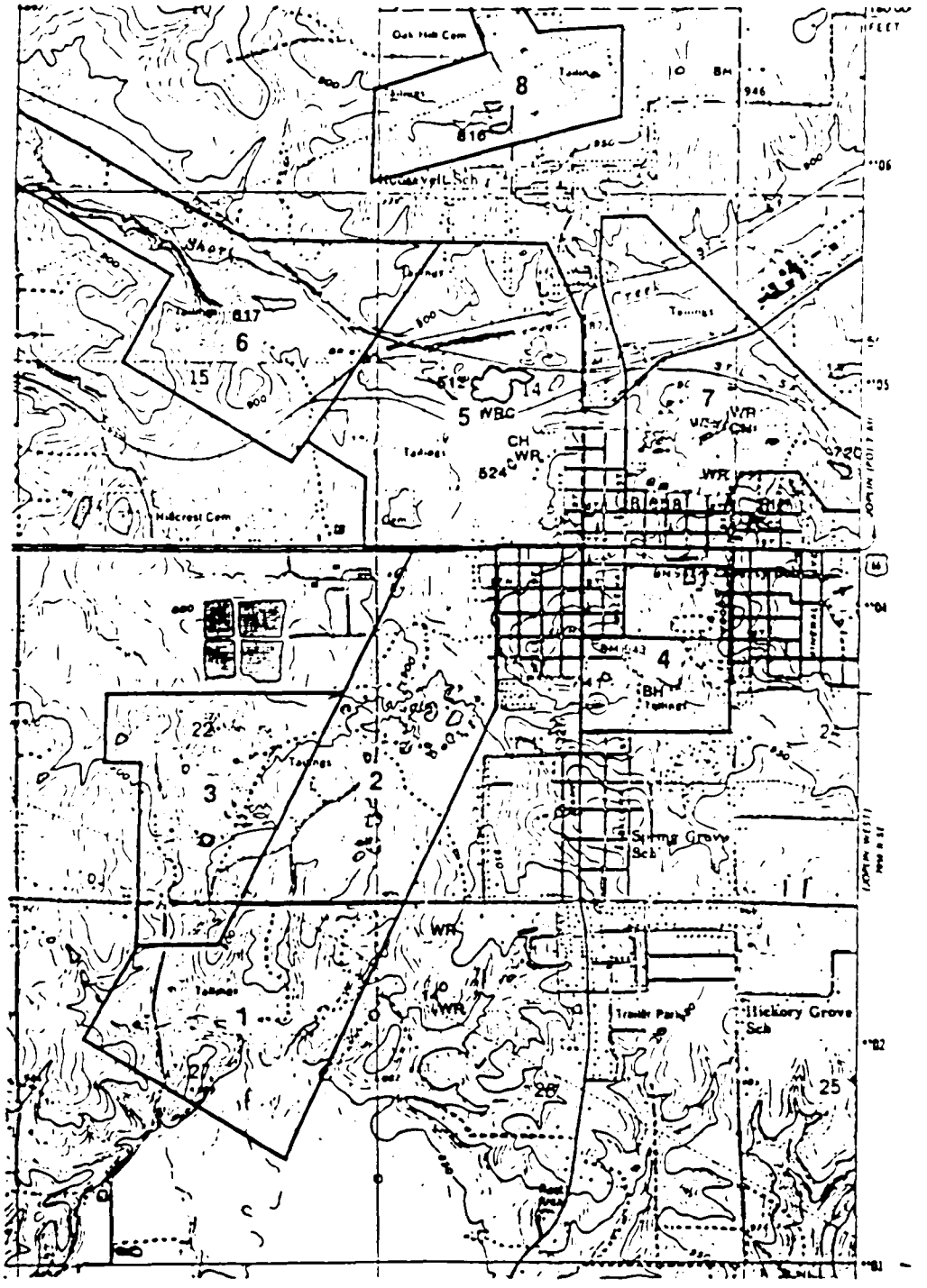
4. collection and chemical analysis of samples of ground waters from subsidence pits and abandoned open pits in EPA Areas 1, 4, 5, 6, 7 and 8;

5. design and preparation of operations plan for pilot-scale batch and flow-through leaching tests;

6. pilot-scale characterization of the leachability of samples using batch and column leach testing;

Figure 2.1 - Location of Sampling Areas - Galena Subsite

1: EPA Area 1 WR: Waste Rock Sample CH: Chat Sample
524: Pond Sample



7. evaluation of the potential effect of the Additional Alternative on ground water quality at the site.

This section of the report presents a description of the activities, methods, and procedures used in the project. The following two chapters present the testing results and the evaluation of the effects of the Additional Alternative based on the pilot-scale testing.

2.2 SAMPLING AND INITIAL SAMPLE HANDLING

2.2.1 Sampling of Waste Rock and Chat

As directed in the EPA work plan (EPA, 1989) and as agreed with the EPA's oversight representative, mine waste-rock was sampled from areas 1, 4, 5, and 7 and chat was sampled from areas 4 and 5 in the Galena subsite (See Figure 2.1). Air photo-based property maps developed by the Cherokee County Assessor were used to locate sampling areas in the field, and samples were collected as channel samples at random locations within each sampling area or pile, using a backhoe bucket. The backhoe splits were placed in a canvas-lined dump truck for transport to the test area for stockpiling and handling.

Waste-rock piles were selected based on previous EPA sampling and on the basis of observations of mineralogy (both gangue and ore)

by the ABC Project Manager and the EPA oversight representative. Chat piles in areas 1, 4, 5, and 7 were surveyed by the EPA oversight representative (accompanied by the ABC Project Manager), using an Aurora Tech field X-ray fluorescence (XRF) unit with a 15 mCi (original) Cd-109 source and field standards developed by CH2M Hill from samples collected and analyzed for the EPA as part of the Phase I Remedial Investigation. Based on the index numbers obtained in the field and the calibration curves developed by the EPA oversight representative, low-zinc chat piles in areas 5 and 7 were identified as suitable for use in the pilot-scale tests. A total of approximately 15 tons of siliceous waste rock, 10 tons of calcareous waste rock and 10 tons of chat were collected from the site by the construction crew under the supervision of the ABC project engineer.

The waste rock and chat piles were homogenized with a backhoe to achieve mixing to the extent practicable. Mixing of the highly variable waste rock was overseen by the ABC project engineer and the EPA oversight representative, and mixing continued until they were satisfied that the piles had been as throughly mixed as practical. Mixing of the chat was assessed using the field XRF unit and continued until the EPA oversight representative judged the mixing as adequate for the purposes of the tests.

Following mixing, the waste rock piles were sieved at a nominal 2 inches to create two stockpiles (one coarser and one finer than 2 inches) of each waste rock type. After thorough mixing of the

plus 2-inch waste rock stockpiles and the chat stockpiles, a subsample of approximately 200 pounds of each rock type was obtained from at least four separate locations on each stockpile, as planned in the Field Operations Plan and directed in the EPA Work Plan. The 200-pound samples were delivered under chain of custody to Tulsa Testing Laboratory for crushing to minus 200 mesh, and splits of these samples will be submitted under chain of custody for chemical analysis and mineralogical analysis by X-ray diffraction (XRD).

2.2.2 Sampling of Ground Water

A two-person sampling crew characterized and sampled Ponds 14, 41, 512, 524, 617, 720, 816, and the "Blue Hole" in Area 4 (Figure 2.1). (Pond designations are those of McCauley (1983); see also Andes, 1988b.) In each case, the ABC crew floated on the pond in an inflatable raft to (1) probe the pond for depth, (2) profile the water-quality field parameters, and (3) collect samples for subsequent chemical analysis. The principal tool for determining water-quality field parameters was a Martek Industries M-XVII instrument, which simultaneously collects data on temperature, pH, dissolved oxygen, conductivity and temperature-corrected conductivity (equivalent to the specific conductance value reported by the laboratory). The Martek tool was calibrated daily in the field for pH and conductivity; it was factory calibrated for temperature and dissolved oxygen immediately before shipment

to the site. At each pond, the crew identified the area of maximum depth, then took field parameter readings at approximately 80%, 50%, and 30% of total depth and at the surface in that area. (Because of a delay in arrival of the Martek instrument from the factory, the Blue Hole was not profiled with this tool. Instead, physical samples were collected with a stainless-steel thief bailer at approximately 80%, 50%, and 30% of total depth and splits of the water were analyzed with a Presto-Tek DSPH-1 multi-purpose meter and pH paper for conductivity and pH. All other ponds were profiled with the Martek tool prior to sampling.)

For ponds that showed relatively little indication of stratification in field parameters (Ponds, 14, 512, 524, 617, 720, and 816), a single water-quality sample was developed by compositing samples collected with the stainless steel thief bailer from approximately 80%, 50%, and 30% of total depth. For Pond 41, which showed significant evidence of stratification in dissolved oxygen, and the Blue Hole, which was not profiled, separate samples were collected at the proportional depths and submitted for chemical analysis. Water quality samples were collected from the raft in new cubitainers; the samples were transferred to laboratory-supplied sample bottles on shore after sampling. Each sample was collected in two splits. One split of 1,000 ml of unfiltered water was sampled for analysis of parameters that are to be done on unfiltered samples (general parameters and major ions, including sulfate). One split of 500 ml was sampled for dissolved metals; this split was filtered

through a 0.45 micron nitrocellulose filter and then acidified to pH 2 (or lower) with nitric acid. After sampling, the bottles were sealed and kept in an insulated cooler on ice until transferred to the laboratories. All samples were handled and documented under chain-of-custody.

Details of the sampling locations and the sampling approach used are provided in Appendix B to this report, a copy of the field notes of the ABC Project Manager and Project Engineer.

2.3 SAMPLE PREPARATION FOR PILOT TESTS

The waste-rock and the chat stockpile samples were individually composited. Following mixing and screening of the stockpiled samples, several steps were performed to prepare materials for testing, consistent with the procedures of the Field Operations Plan (see Appendix B for details):

1. Splits of waste rock (in three grain-size/handling fractions: plus 2"; minus 2"; unscreened) and chat were collected and prepared for various batch leaching tests which were intended to test materials properties parametrically;

2. Plus 2 inch waste rock and chat samples were mixed with the backhoe bucket to the extent practicable for the pilot-scale flow-through leaching tests (see discussion below); and

3. Samples of ground water were collected for use in the various batch and flow-through tests. Samples of the test water were collected for chemical analysis before testing began, as well as after the 24-hour batch tests and throughout the flow-through tests.

The decision to mix intimately (rather than layer or randomly place) waste rock and chat was made by EPA, based on a consideration by the EPA that, for the scale of the proposed pilot tests, it was considered conservative (i.e., it would not underestimate potential effects) to mix the materials to maximize potential reactions and reaction rates and minimize the potential for channeling of flow in the flow-through tests. Two points were noted by all parties in developing and reviewing the field operations plan addendum for the leach tests:

1. There is no contemplation by any party of intimately mixing waste rock and chat were a full, field-scale implementation of the Additional Alternative to be performed. The agreement to mix samples for the purpose of these tests is not an endorsement by the Participating PRPs of mixing as a viable or technically justified materials-handling step nor as an element of the Additional Alternative.

2. Because of the mixing of materials, including, but not necessarily limited to, the effects of self-grinding during the elaborate and extensive mixing process, it is likely that

leaching will be overestimated by these tests in comparison to actual field-scale disposal.

2.4 LEACHING EXPERIMENTS

Two styles of leaching experiments were performed in the field at the test facility developed near Pond 524: batch testing of various solid and water samples in 55-gallon drums, and flow-through leaching of large samples of waste-rock and chat using ground water from Pond 524.

2.4.1 Batch Testing

Batch leaching tests were perfomed (1) to obtain a rapid estimate of the extent to which the samples could be leached, and (2) to compare with the more elaborate and costly flow-through tests. Twenty-four-hour batch leaching tests were performed, modeled on EPA protocol SW924, using actual site ground waters and a water-rock ratio of 2:1. Evaluation of the chemical data from the various leaching experiments on waste rock provides data that can be used to assess the nature of solutions that could be derived by leaching of the waste materials. Additionally, the data provide information about the processes that are likely to control the fate of metals.

Eighteen batch tests were performed. Tests 1-12, performed in 55-gallon drums, assessed various combinations of waste materials and

Subsite ground waters. Tests 8 and 9 were replicate batch tests. Tests 13 and 15 assessed the potential impacts of varying the water:rock ratio. Test 14 was conducted in a painted (epoxy-based paint) barrel to assess the impacts, if any, of the soft-steel container on water quality.

In addition, a 24-hour batch test was performed in each of the three large flow-through tanks prior to commencing the flow-through portion of the experiment. All three tanks were painted with an epoxy-bsed paint before use to minimize any effects of the steel on water quality.

2.4.2 Flow-Through Tests

Two flow-through leaching tests were devised (one of which was performed in duplicate to test the reproducibility of the data), in order to simulate the potential differences that might exist from leaching calcareous and siliceous waste rock. The as-designed and as-built drawings are presented as Figures 2.2 and 2.3. Test methods are detailed in Appendices A and B, and a summary is provided below:

- The three tanks were filled with pond water and allowed to sit (closed) for 24 hours to de-air. At the end of this time, the water was sampled, tested for field parameters and split for treatment (as appropriate) and shipment to the chemical laboratories. Following sampling, the tanks were drained.

Figure 2.2 - Flow Through Test Tank

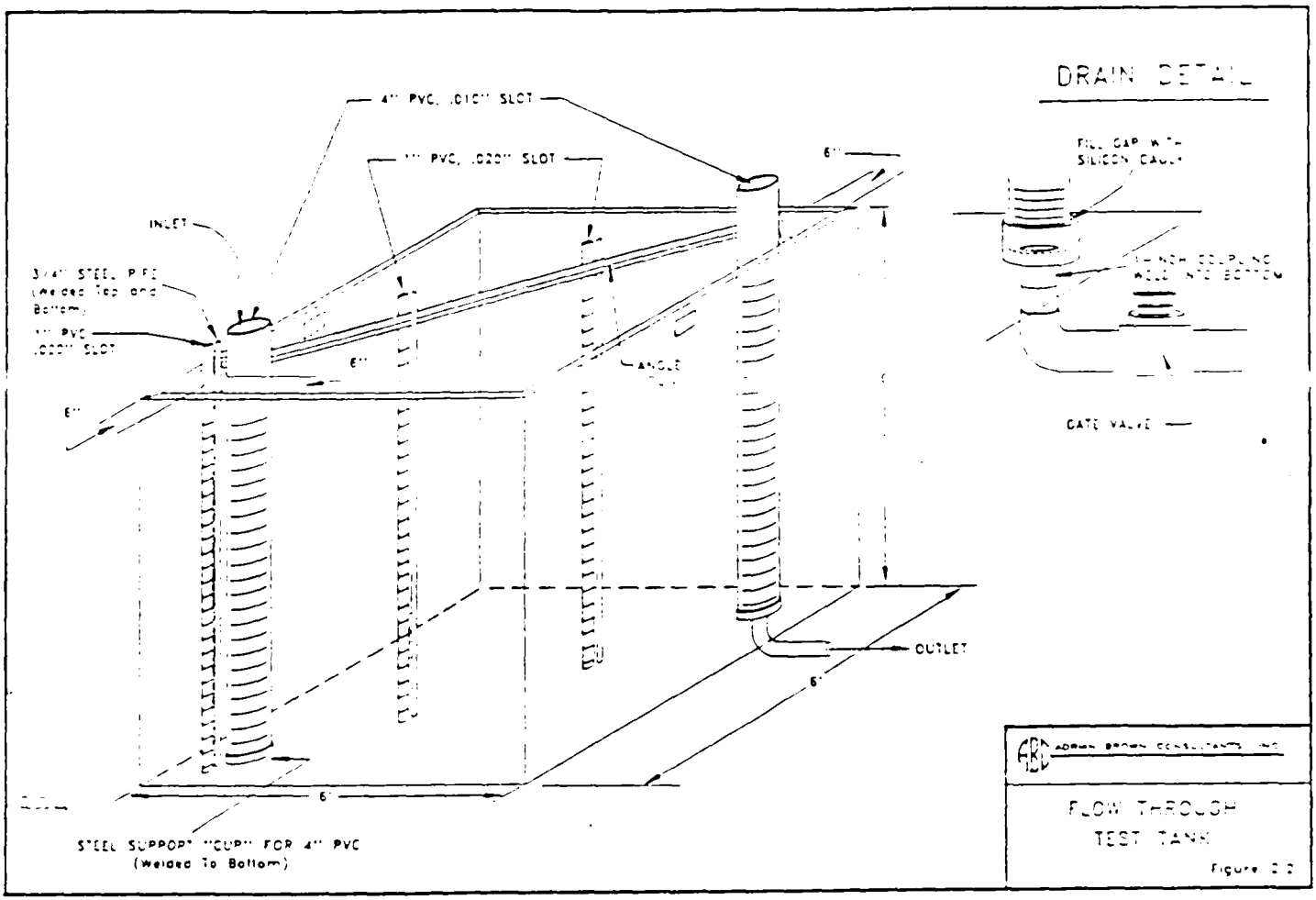
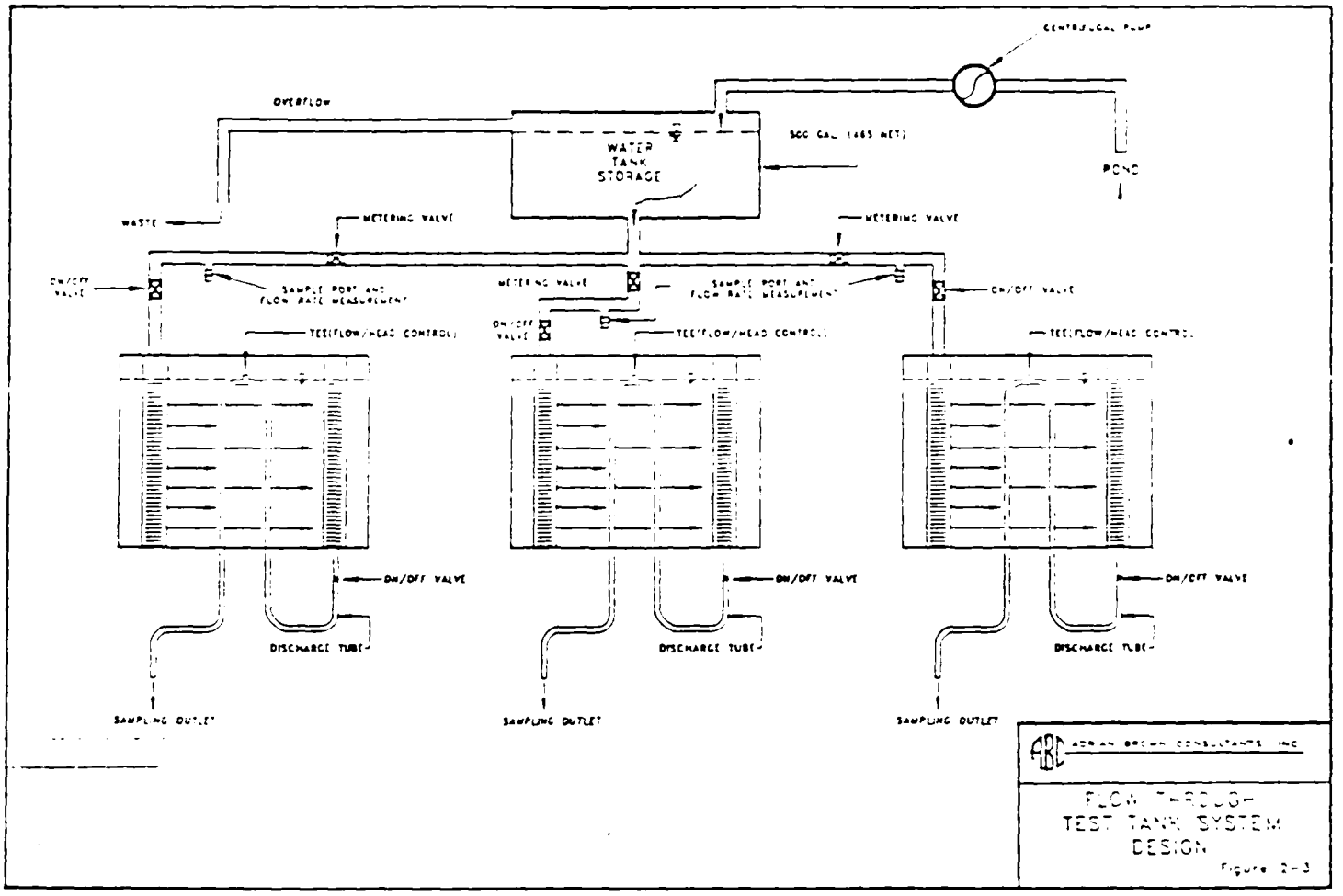


Figure 2.3 - Flow Through Test Tank System Design



- For actual leach testing, the tanks were loaded first with test water followed by the waste rock-chat mixture. The rock charge was saturated with pond water and the volume of that water carefully measured as filling proceeded, until the tank was loaded to the overflow vents. Water level (head) in the filled tank was controlled with the plastic manometer tubing at an elevation just above the top of the rock (Figure 2.3). The total volume of water in each fully charged and saturated tank was computed by summing the partial volumes needed to saturate the charge and the additional volume needed to keep the water level above the rock.

- The tanks were left fully loaded with rock and water for 24 hours. At the end of the 24-hour batch test, the tank was drained, and samples were collected at three time intervals for each tank, representing, the early, middle and late effluents. These samples were tested for field parameters and split for treatment (as appropriate) and shipment to the chemical laboratories for analysis. Following the third sampling, the tanks were drained.

- The tanks were refilled, with the volume again being measured by flow out of the header tank. When the tanks were filled, the first cycle of the flow-through test began.

- Flow throughout the tests was maintained at 2 gallons per minute via the valving system, and the head in each tank was maintained at a constant elevation via the manometer system, as shown in Figure 2.3.

- Three test cycles were performed. In Cycle 1, the charge was leached with water from Pond 524 that passed through the 500-gallon header tank. Outflow samples were collected at pore volumes 1/2, 1, 2, 3, 6, 10 and 15. (The Operations Plan called for the first cycle to end after pore volume 10, but during discussions between ABC, EPA and CH2M Hill over issues of experimental protocol, the first cycle was extended to fifteen pore volumes.)

  Cycle 2 was designed to test the potential effects on water quality of introducing a large volume of "rainwater" into the system in such a manner that it mixes with the ambient ground water before that mixed water can react with the disposal charge. The conceptual model for this cycle is as follows:

  - A major rainfall event (e.g., a high intensity convective storm or the highest intensity portion of a longer-term frontal storm) provides enough precipitation to produce a 1:1 mixture of ambient ground water and "rainwater" in the saturated zone of the major subsidence pits.

    For pond 524, with a total volume of approximately 1.68 million gallons, this amounts to a "rainwater" component

flowing past the model disposal charge of 840,000 gallons (approximately 2.5 acre-feet of rainwater). For an up-gradient capture area of about 2 - 3 acres, this amounts to about 1 foot of rainfall, assuming 100% infiltration or capture, and very-short-term mixing in the groundwater system. All of these assumptions seem extremely conservative with respect to the likely impact of rainwater on the groundwater system, but they were developed to provide a suitably conservative analysis of the potential for impact of rainwater on the ground water. During and after thunderstorms during the actual pilot test program, water levels in some ponds were observed to raise and fall over a few days by no more than about 2 feet. For Pond 524, this amounts to only about a 10% change in volume, presumably reflecting about a 10% rainwater/overland flow input, instead of the 50% modeled in the Cycle 2 test.

- The ground water - rainwater mixture flows through the disposal charge, potentially reacting with the materials.

- Following the slug of mixed water, the groundwater system returns to its ambient conditions, as represented in these tests by Pond 524. The more normal ground water displaces the mixed water as it flushes through the system. Eventually, the ground water returns to its normal range of chemical conditions.

Cycle 2 introduced 1 pore volume of a mixed water, followed by 9 pore volumes of water from Pond 524. As described in the Field Operations Plan, the mixture was produced as follows:

- Galena system water (derived from the Roubidoux Formation and sampled at the Galena Fire Department) was introduced into a 500-gallon water tanker.

- The pH of the system water in the tanker was adjusted to approximately pH 5 using a 60% H_2SO_4 - 40% HNO_3 solution. This method of pH adjustment is derived from EPA Method 1312, proposed for use in RCRA leaching for categorization of high-volume - low-hazard wastes. The pH 5 value is that proposed by EPA for testing west of the Mississippi River. The Galena system water was chosen as an initial water for developing a synthetic "rainwater" on the basis of its relatively low dissolved load and its availability in large volumes nearby. (Measurements of field parameters on samples collected for use in the tests are fully consistent with published data in Spruill (1984) and the RI (1986) with respect to pH, dissolved oxugen and conductivity, indicating that representative samples of the system water were used in the tests.) Two 300-gallon batches of "rainwater" were produced. The pH of the first batch was 4.99; the pH of the second batch was 4.90. Both

of these are considered sufficiently close to pH 5 to meet the pH criterion for the test water.

- Pond water was pumped into the 600-gallon tanker along with the pH-adjusted "rainwater". The water level in the header tank was dropped to about 50 gallons, and the pond water - "rainwater" mixture was pumped from the tanker to the header tank. The process was repeated twice for each tanker mixture, producing a total of approximately 1,200 gallons of nominally 1:1 mixed water.

- The flow rate through the test tanks was held at 2 gallons per minute per tank during the entire cycle, producing a flow of 1 nominal pore volume per tank at the same flow rate as during all the rest of the flow-through test.

- Samples were drawn at pore volumes 1/4, 1, 2, 3, 6 and 10 of Cycle 2.

Cycle 3 continued the flow-through test using water from Pond 524 for an additional 10 pore volumes beyond Cycle 2. Samples were drawn at pore volumes 1, 3, 5 and 11 of Cycle 3.

o Because of the extension of Cycle 1 and the cross-over times for Cycles 2 and 3, the total flow through test flowed approximately 38 pore volumes of test waters through each of the three test charges, or approximately 15,000 gallons per test. The total testing time was approximately 7 days, including the initial 24-hour batch tests.

- Following the conclusion of sampling for the Cycle 3 flow-through tests, the tanks were drained in a step-drawdown test to assess hydraulic conductivity of the test charges.

- After completion of the drawdown tests, the tanks were resaturated, the plumbing disconnected, and the tanks sealed against intrusion, pending review of the laboratory data. When EPA has reviewed the data and determined the test to be complete, the tanks will be disassembled and the test area policed, per the Field Operations Plan.

2.5 CHEMICAL ANALYSIS

All water samples were collected for analysis of a selected list of parameters, stipulated in the EPA work plan (Appendix A), at Professional Services, Inc. - Bruce Williams Division (Bruce Williams), Joplin, Missouri. Parameters analyzed at Bruce Williams were:

SHORT LIST CHEMICAL PARAMETERS

pH
Specific Conductance
Oxidation- Reduction Potential (ORP)
Sulfate
Dissolved Cadmium
Dissolved Lead
Dissolved Zinc

Approximately 10% of the water samples were collected as quality control splits, including blanks and replicates to Bruce Williams as well as replicates which were transported under

chain-of-custody for analysis at Core Laboratories, Aurora, Colorado. Core Laboratories were asked to analyze the water samples for the following parameters:

QUALITY CONTROL ANALYSES

pH
Specific Conductance
Total Dissolved Solids
Major Cations (Na, K, Ca, Mg)
Major Anions (HCO3/CO3, SO4, Cl, F)
Dissolved Metals (Al, As, Ba, Cd, Cr, Co, Cu, Fe, Pb, Mn, Hg, Se, Ag, V, Zn)

Additionally, access to sampling was provided to the EPA oversight personnel throughout the tests, and they collected about 10% of the samples as splits for analysis at an EPA-selected Contract Laboratory. The EPA laboratory was to be asked to analyze for the parameters shown in Table 1 of the Work Plan (Appendix A).

The solids will be analyzed at Core Laboratories, with quality control samples analyzed at Kansas City Testing Laboratories, when the samples are delivered by Tulsa Testing Laboratories. The solids will be analyzed by a total digestion method for the same major ions and metals as listed above for the water QC samples. In addition, the solids will be tested with the EPA's Toxicity Characteristic Leachate Procedure, EPA Method 1311. Core Laboratories (or a subcontractor approved by the ABC Project Manager) will perform x-ray diffraction analyses on splits of the solids to determine the mineralogy of the samples.

All analyses at all laboratories used in this program were performed in accordance with standard EPA procedures, for those

procedures that have been published. Secondary sources for analytical methods include Standard Methods for the Analysis of Water and Wastes, ASTM, USDA, NIOSH, and others. Copies of the analytical Statements of Work are on file at Adrian Brown Consultants and at the laboratories.

3.0 RESULTS

Various mixtures of waste rock (both siliceous and calcareous) and low-zinc chat were subjected to a range of tests to develop an understanding of the leaching and permeability characteristics of the test mixtures. The battery of tests included chemical and mineralogical analysis, 24 hour batch leaching, and 30-40 pore-volume flow-through leaching. The results are presented below.

3.1 BASELINE MATERIALS CHARACTERISTICS

Evaluation of the data on the starting chemistry of ground waters and solids provides not only information used to assess baseline characteristics, but also may provide information about the processes that are likely to be important in the fate of metals and other solutes.

3.1.1 Waste Rock and Chat Head Grades

Total metals analyses from splits of the waste rock used in the December, 1988 tests (ABC, 1988a) are presented Table 3.1; analyses for the composited chat sample are presented in Table 3.2. These tables will be revised and expanded to include total metals concentrations for the samples selected as part of the pilot testing when those results become available.

Table 3.1 - Total Metals Concentrations in Various Waste Rock Samples

METAL		MINUS 1" FEED FOR COLUMN AND BATCH TESTS	-100 MESH FEED FOR MILLING OF TEST TAILING
Cadmium	mg/kg	58	40
Iron	mg/kg	8,332	8,200
Lead	mg/kg	1,393	4,230
Manganese	mg/kg	1,126	140
Zinc	mg/kg	13,424	7,000

Table 3.2 - Total Metals Concentrations in the Composite Chat Sample

METAL	UNIT	CHAT
Cadmium	mg/kg	10
Iron	mg/kg	7,649
Lead	mg/kg	486
Manganese	mg/kg	972
Zinc	mg/kg	2,999

Until the new data become available, the 1988 PRP data are considered sufficiently reliable to be useful for the purposes of this draft report.

The head grades indicate that the materials used for the 1988 waste rock testing program are well within the range of values previously determined for waste rock at the Galena subsite. In fact, the zinc and manganese values are distinctly toward the high end of the range that had previously been reported. Note, too, that while the total metals values reported by AMAX Extractive Research and Development Laboratory for the sample that was milled are generally comparable with the waste-rock sample analyzed by Core Laboratories, the AMAX split was lower in zinc but higher in lead. The differences are probably due to a "nugget effect": the impact on total metals of even a small, but high-grade portion of sphalerite (e.g., in the case of the Core sample) or galena (e.g., the AMAX sample). These examples of nugget effects show the inherent difficulty of preparing a "representative" sample for chemical testing. It was, in part, to address these sampling issues that the test protocols of the EPA Work Plan and the ABC Field Operations Plans stipulated the collection, stockpiling and mixing of very large (on the order of 10 tons) samples of each of the three types of solid waste materials.

3.1.2 Baseline Water Quality

Table 3.3 presents the data on water quality in Ponds 14, 41, 512, 524, 617, 720, 816, and the Blue Hole. These ponds, whose locations were identified in Figure 2.1, represent the major bodies of standing ground water in subsidence areas and abandoned open pits in EPA Areas 1, 4, 5, 6, 7, and 8, covering the full geographic area of the Subsite in which there is substantial standing water in subsidence areas available for disposal. (EPA Areas 2 and 3 contain little or no ground water in subsidence pits; see Andes, 1988b).

It is clear from these data that there is a substantial range of water quality across the site. All of the ponds have relatively low total dissolved solids concentrations, almost certainly less than 500 mg/l, based on conductivity values between 128 and approximately 550 umho/cm. Sulfate concentrations range from 23 to 224 mg/l, all within the Secondary Maximum Contaminant Level (40 CFR Part 143). Several of the ponds have near neutral pH and low to non-detectable values of dissolved cadmium and lead. On the other hand, some of the ponds, for example, the Blue Hole in Area 4, have pH values around 3.5 to 4 and, as expected, a few tenths of a part per million (mg/l) dissolved cadmium and lead and a few parts per million (mg/l) dissolved zinc. The range of observed, ambient values shown in Table 3.3 will be referred to below as the baseline or baseline range of water quality.

Table 3.3 - Baseline Water Quality - Field Characterization Phase

Note: "-" indicates "less than"

As was pointed out in the Phase I Remedial Investigation (RI) (EPA, 1986) and Spruill (1984), despite the geographical correlation of abandoned mines and mineralized ground water, the causal connection between mining wastes and ground water "contamination" is tenuous. In the RI, zinc is the only indicator parameter that could be shown statistically to be elevated in drinking water wells located down gradient of mine workings and wastes; no statistically discernible increase over baseline ranges was observed for cadmium, lead, iron, or net alkalinity (RI, Pages 46 to 49; Figures 4-7 to 4-9). The lack of covariance between zinc and the other indicator species to be expected from the CH2M Hill conceptual model of acid generation and metals dissolution suggests that the situation is not as simple as postulated in the RI.

The new data of this study provide further evidence against a simple causal connection between mining wastes and shallow ground water degradation. All 8 of the ponds that were sampled in this baseline study are surrounded by mining wastes, yet the range of observed water quality, as shown in Table 3.3, is large. Consider the differences in water quality between Pond 41 and the Blue Hole, which are located less than 100 meters apart in Area 4. Pond 41, evidently a subsided shaft based on its form and the characteristics of the surrounding waste materials, has a pH of about 7, conductivity of about 530 umho/cm, low dissolved oxygen, and low to non-detectible values of metals. In contrast, the Blue Hole, also a subsided mining feature, has a pH of about 3.5,

conductivity of about 370 umho/cm, relatively high dissolved oxygen (based on laboratory measurements of oxidation reduction potential (ORP)), and dissolved metals in the tenths of parts per million (Cd) to a few parts per million (Pb, Zn).

Rather than hypothesize a causal connection between mining wastes (or even mining activity) and degradation of shallow ground water quality (if any such degradation exists), the evidence can be formulated equally well, if not better, in terms of a common-cause connection (e.g., Reichenbach, 1956). In the common-cause formulation, mining and mining waste, on the one hand, are clearly associated causally with the presence of mineralized ground. On the other hand, there is compelling geochemical reason to believe that ground water recharging to and flowing through the mineralized and fractured ground of the Galena ore field would produce, at least locally, acid waters and elevated sulfate, total dissolved solids and dissolved metals (Angino, 1988). In light of this information, the effects of natural mineralization of the area (including fracturing, brecciation, and silicification, as well as sulfide mineralization) are the common cause of the mining/mining waste and the observed water quality. (This is not to say that, necessarily, the water quality observed today is identical to the water quality that would have been observed had there been no mining. This is a hypothetical case that cannot be tested for the Galena case. However, note the discussion in Angino (1988) of baseline water quality around other, recently

discovered and undeveloped Pb-Zn deposits, such as Red Dog in Alaska.)

3.2 BATCH LEACH BEHAVIOR

The batch test data for Tests 1-15, presented in Table 3.4. Table 3.4 and the corresponding Figure 3.1, show that:

1. The pH rises by about 1 to 1.4 pH unit and oxidation reduction potential (ORP) (and dissolved oxygen) decreases during the batch tests. The changes in pH and ORP indicate that the expected classes of chemical reactions - at least, acid-base and redox reactions - are occurring, and the change in conductivity by about 50 to 70 umho/cm indicate that discernible changes in total dissolved solids, perhaps on the order of 30 to 50 mg/L, are occurring.

   Most of the increase in total dissolved load (reflected in the conductivity) is accounted for by SO4 and the equivalent cation load needed to (approximately) balance the sulfate charge. Very little metal is leachable from waste materials tested. In batch tests 1 - 15, Cd increases by about 0.02 - 0.1 mg/l; Pb increases by about 0.5 - 1 mg/l, and Zn increases by about 5 - 10 mg/l.

Table 3.4 - Batch Leaching Test Data

Note: "-" indicates "less than"

GALENA PILOT TEST - ADR TEST - BATCH LEACH TEST

	WATER/SOLID	DEPTH (FT)	T (°C)	pH	Eh (mv)	COND (mmhos/cm)	COR. COND (mmhos/cm)	COND (mmhos/cm)	pH	ORP (mV)	SO4 (mg/L)	Cl (mg/l)	Pb (mg/L)	Zn (mg/l)
1	524/+2" SIL/CHAT		[illegible]	1.72	2.73	529	542	470	3.9	372	211	0.07	0.15	31.1
2	521/+2"CAL/CHAT		26	1.11	2.95	521	539	465	4	354	264	0.05	0.2	39.1
3	524/UNSCR SIL/CHAT		[illegible]	1.78	2.69	503	539	450	4.2	319	241	0.09	0.16	37.1
4	524/UNSCR SIL		-1.1	4.76	2.71	511	535	450	4.2	325	234	0.08	0.2	37.1
5	524/-2" SIL		-1.1	4.76	2.3	503	526	455	4.1	316	230	0.1	0.22	43
6	521/CHAT		-0.1	4.67	1.17	501	516	460	4	342	244	0.1	0.2	43.1
7	11/+2" SIL/CHAT		-2.3	6.66	1.6	125	116	110	5.7	215	47	0.02	-0.01	4.58
8	BLUE HOLE/+2" SIL/CHAT		27	4.15	1.15	355	393	355	3.4	549	148	0.1	1	11.9
9	BLUE HOLE/+2" SIL/CHAT		-1.4	4.2	1.57	356	393	325	3.4	537	147	0.1	0.95	13.9
10	816/+2" SIL/CHAT		-0.9	1.03	1.2	305	317	280	3.4	478	116	0.06	0.15	14.9
11	720/+2" SIL/CHAT		-1.3	6.91	1.51	274	255	220	7.2	301	46	-0.01	-0.01	0.49
12	617/+2" SIL/CHAT		[illegible]	7.22	0.4	319	216					-0.01	-0.01	2.1
13	1:1/+2" SIL/CHAT		11.0	1.91	0.34	602	535					0.14	0.31	39.6
14	PAINTED/+2" SIL/CHAT		12.7	4.76	1.03	593	530					0.12	0.33	52.3
11D	PAINTED/+2" SIL/CHAT											0.1	0.3	53.1
15	1:2/+2" SIL/CHAT		11.1	1.52	0.05	597	513					0.12	-0.01	39.5

BATCH TEST - 24-HOUR, AGITATED AT WATER ROCK 2:1

1	524/+2"SIL/CHAT	26	5.99	0.36	564	573	490	5.2	269	318	0.12	0.4	55.2
2	521/+2"CAL/CHAT	26.1	6.12	1.25	591	609	510	6.1	218	283	0.14	0.23	50.3
3	521/UNSCR SIL/CHAT	26.5	5.91	1.35	561	582	490	5.8	201	255	0.17	0.66	58.7
4	524/UNSCR SIL	26.9	5.96	0.77	546	567	460	5.5	189	210	0.2	1.1	49.7
5	524/-2" SIL	26	5.9	0.46	511	593	500	6.2	148	282	0.19	0.8	35.1
6	524/CHAT	25.5	5.78	1.37	563	586	490	5.5	221	286	0.15	0.4	53.5
7	11/+2" SIL/CHAT	21.8	6.05	0.75	183	210	172	5.8	215	75	0.13	0.15	22.8
8	BLUE HOLE/+2" SIL/CHAT	21.3	6.14	0.78	390	422	340	5.3	218	174	0.2	0.17	41.3
9	BLUE HOLE/+2" SIL/CHAT	21.7	6.42	0.19	371	402	315	5.5	215	160	0.21	0.18	41.2
10	816/+2" SIL/CHAT	21.2	5.91	0.45	313	337	260	5.5	212	132	0.15	0.19	42.2
11	720/+2" SIL/CHAT	21.5	6.4	0.31	280	312	215	6.5	212	76	0.07	0.08	15.3
12	617/+2" SIL/CHAT	20.6	6.31	-0.09	301	326								
12D	617/+2" SIL/CHAT											0.08	0.1	1.88
13	1:1/+2" SIL/CHAT	21.9	6.12	-0.13	702	602								
14	PAINTED/+2" SIL/CHAT	1.1	6.00	0.16	689	590								
15	1:2/+2" SIL/CHAT	1.9	6.02	-0.10	756	667						0.38	0.363	8.64

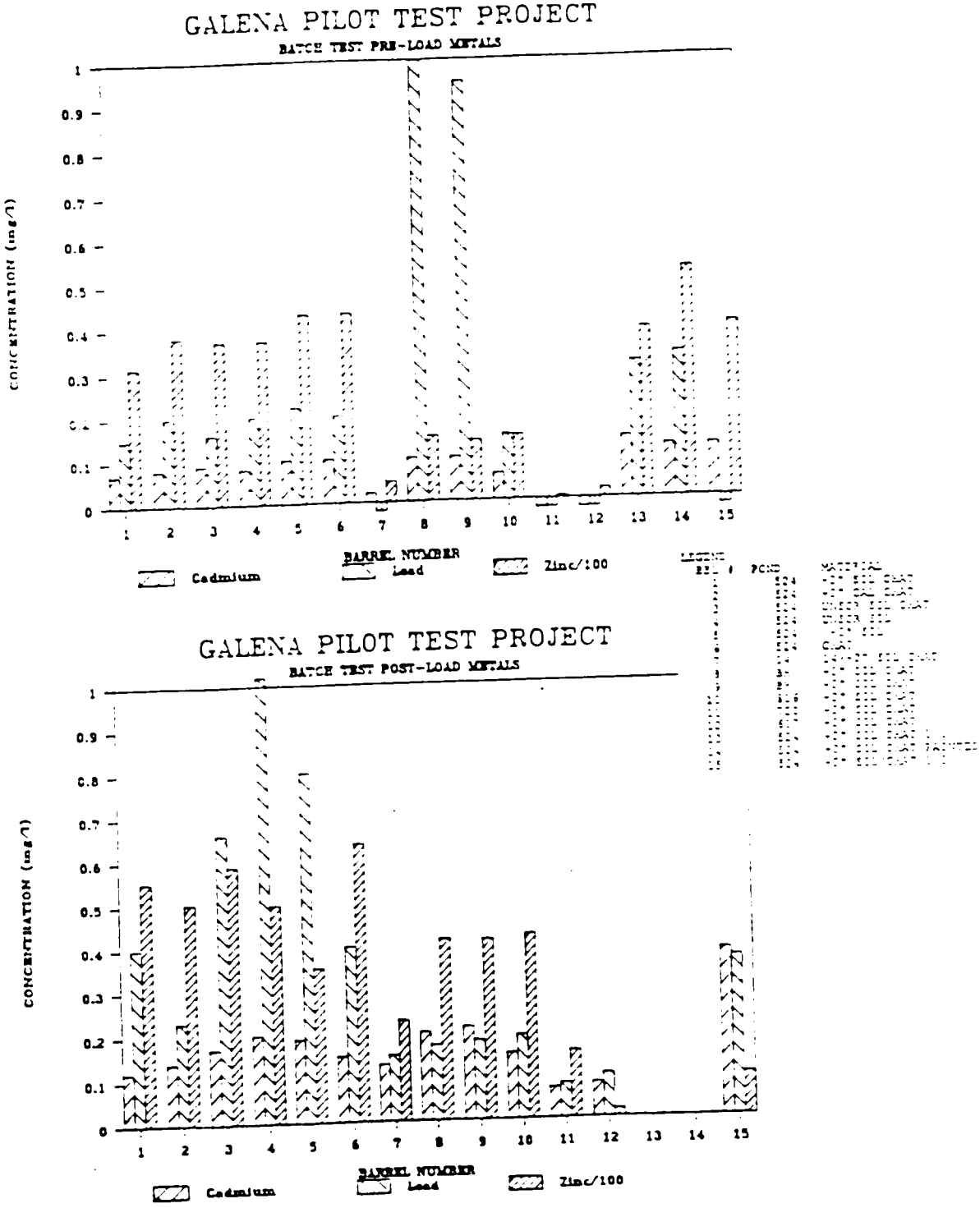
Table 3.4 - Batch Leaching Test Data (Con.)

GALENA PILOT TEST - ... DATE CREATED 30-Jun-89

BATCH TEST - DIFFERENCE (WATER QUALITY AFTER TEST MINUS WATER QUALITY BEFORE TEST)

			Field					Joplin Lab						
	WATER/SOLID	DEPTH	T	pH	DO	COND	COR. COND	COND	pH	ORP	SO4	Cd	Pb	Zn
		feet	deg C	su	ppm	umho/cm	umho/cm	umho/cm	su	mV	mg/L	mg/L	mg/L	mg/L
1	521/+2"SIL/CHAT		-0.3	1.26	-2.37	36	36	20	1.4	-103	71	0.05	0.25	23.8
2	524/+2"CAL/CHAT		-0.6	1.39	-1.67	70	70	45	2.1	-166	19	0.06	0.03	12.2
3	524/UNSCR SIL/CHAT		1	1.13	-1.31	58	11	30	1.1	-118	11	0.08	0.5	21.6
4	524/UNSCR SIL		1.1	1.2	-1.94	35	29	10	1.3	-136	6	0.12	0.9	12.6
5	524/-2" SIL		1.6	1.11	-1.84	71	57	45	2.1	-168	52	0.09	0.58	-7.9
6	524/CHAT		-0.5	1.12	0.2	62	70	30	1.5	-121	52	0.05	0.2	20.4
7	11/+2" SIL/CHAT		-2.5	-0.61	-0.85	58	61	62	-0.1	0.4	27.9	0.11	0.16	18.22
8	BLUE HOLE/+2" SIL/CHAT		-2.7	1.96	-0.97	5	29	-15	1.9	-330.7	25.7	0.1	-0.83	26.1
9	BLUE HOLE/+2" SIL/CHAT		-2.7	2.22	-1.39	-15	9	-40	2.1	-321.6	12.7	0.11	-0.77	27.4
10	816/+2" SIL/CHAT		-1.6	1.99	-0.75	8	20	-20	2.1	-265.6	15.7	0.09	0.04	27.3
11	720/+2" SIL/CHAT		-2.9	-0.51	-1.2	6	27	25	-0.7	-83.6	29.7	0.08	0.09	14.81
12	617/+2" SIL/CHAT		0.1	-0.55	-0.48	62	50					0.01	0.01	-2.1
13	1.1/+2" SIL/CHAT		1.3	1.15	-0.47	100	87					-0.11	-0.31	-38.6
14	PAINTED/+2" SIL/CHAT		2.6	1.21	-0.57	96	60					-0.12	-0.33	-52.3
15	2.1/+2" SIL/CHAT		0.5	1.2	-0.15	159	121					0.26	0.373	-29.86

Figure 3.1 - Comparison of Batch Leaching Test Data - Selected Metals



2. The fine-grained (minus 2 inch waste-rock and the chat) portions of the waste materials include higher amounts of leachable metals and other reactive species (see conductivity, Eh, pH), given the experimental conditions. However, the ranges of metal increases identified in bullet 1 above, apply to these samples as well.

   This suggests that there is relatively little advantage in terms of long-term water-quality impacts to be gained by including special materials handling steps such as screening of waste rock.

3. Results are not signficantly different for batch tests conducted with waters from different ponds or different water-rock ratios tested. This suggests that the impacts of the Additional Alternative can be assessed reliably on a Subsite-wide basis using the data generated by these tests.

The results for the three large-scale batch tests conducted at the initiation of the flow-through program are qualitatively similar to the small-scale tests in several important respects; these data are also shown in Table 3.4. As can be seen from Table 3.4, the pH rose and the ORP fell, as in the smaller batch tests. Conductivity, sulfate and the indicator metals rose by factors of about 2 to 3 above the values seen in Batch Tests 1-15.

The batch-test data are best interpreted as indicating that the short-term behavior of waste rock is dominated by surface-area

effects. It is considered that crushing the rock during mixing and emplacement in the large-scale tests increased the total surface area, exposed fresh faces to redox and other chemical reactions and subsequent dissolution of metals and sulfur. Furthermore, the intimate mixing allowed the test water to contact more fine-grained material than is to be expected if the grain sizes are inhomogeneously placed, which would allow intrinsic permeability of the materials to control flow. This interpretation leads to two important conclusions:

1. If metal release inthe very short term after placement is to be minimized, it is preferable to minimize total surface area and the exposure of fresh mineral surfaces, other things being equal. This implies that materials handling should be minimized in an actual remedial action and that in no case should materials be intimately mixed.

2. The rock that has been mixed (and therefore crushed to some extent) for the flow-through tests appears to have about 2 to 3 times greater leachability of cadmium, lead and zinc than the same materials that were not mixed to the same extent. This suggests that using the results of the batch and flow-through tests of this pilot program as a basis for computation of the release of metals from undisturbed waste rock on site will lead to a considerable over-estimate of likely true impacts.

3.3 FLOW-THROUGH TESTING BEHAVIOR

The actual flow-through test results for waste rock - chat mixtures show great consistency both between the replicate tests with siliceous waste rock and even between the siliceous and calcareous waste rock tests (Table 3.5; Figures 3.2A - 3.2C). Furthermore, the flow-through test results from approximately pore volume 2 of the first cycle through the remainder of the test are remarkably consistent from test to test; all show constant pH, falling metals and sulfate concentrations and falling total dissolved loads (as shown in the conductivity values); and all of these later data fall within the range of the 55-gallon batch tests (Batch Tests 1-15) and, ultimately, of the background water quality for ground water in Pond 524.

In all three flow-through tests, pH rises and ORP decreases during the initial batch test and through the first one to two pore volumes of the flow-through test. The pH initially rises from below about 5 (Pond 524 water) to above 6.5, which indicates that the rock has some capacity to off-set any acidity that may be generated. Following the flushing of the initial batch test, the pH of the solution remains in the range of appropximately 5.8 to

Table 3.5 - Flow-Through Leach Test Data

Table 3.5 - Flow-Through Leach Test Data (Con.)

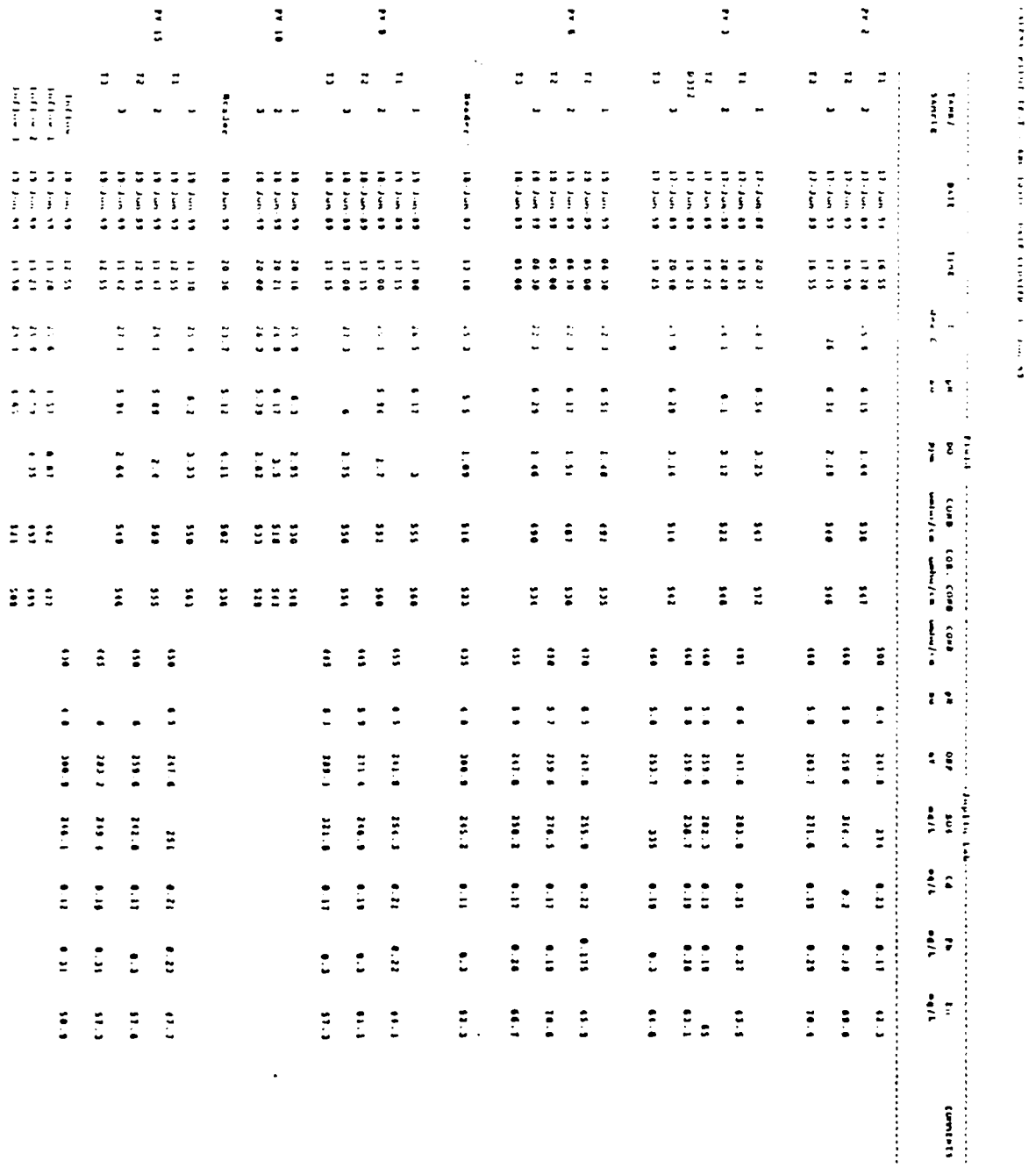


Table 3.5 - Flow-Through Leach Test Data (Con.)

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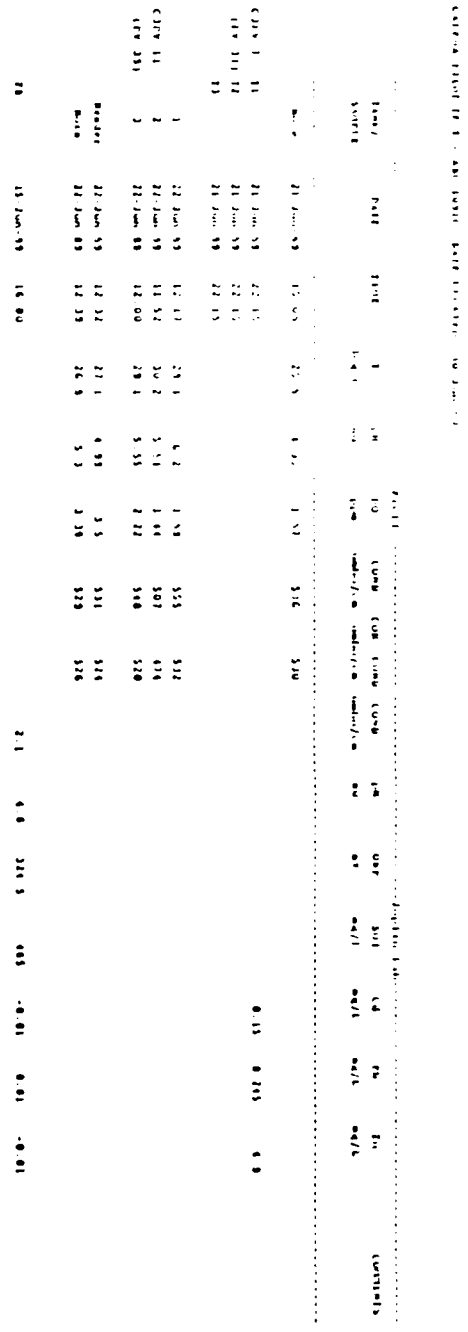


Figure 3.2A - Flow-Through Leach Results

ZINC IN TANKS 1-3

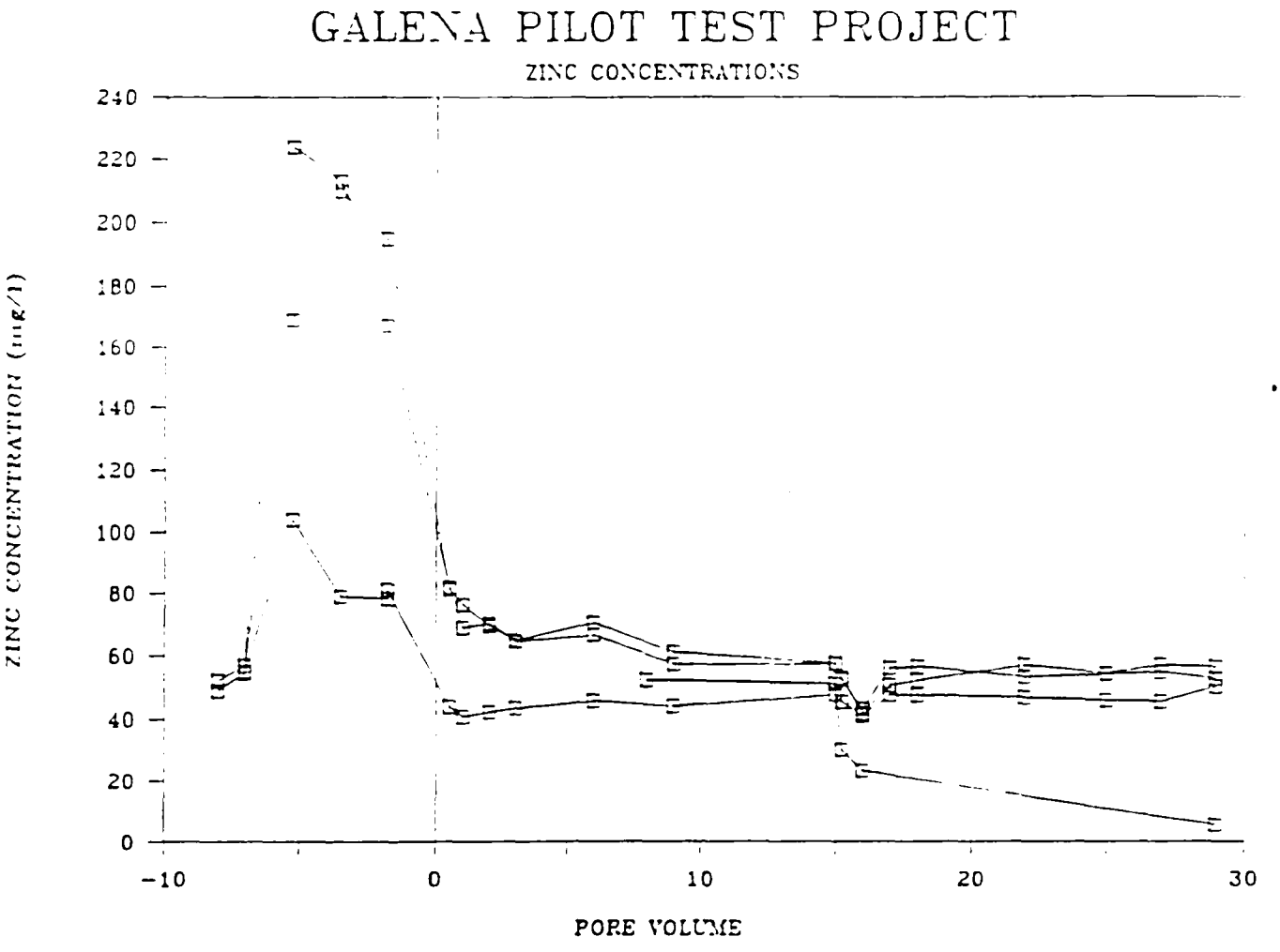


Figure 3.2B - Flow-Through Leach Results

CADMIUM IN TANKS 1-3

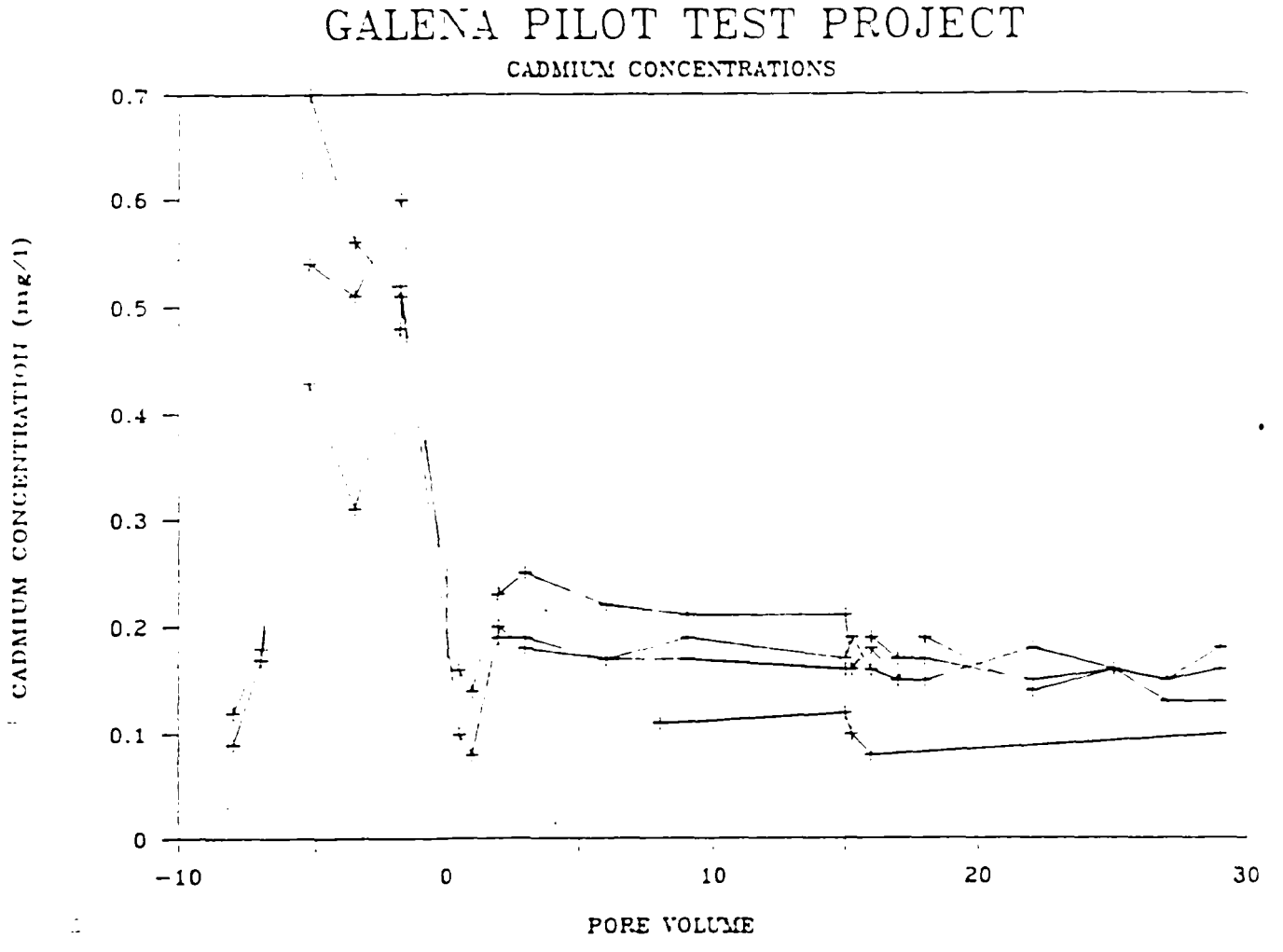


Figure 3.2C - Flow-Through Leach Results

LEAD IN TANKS 1-3

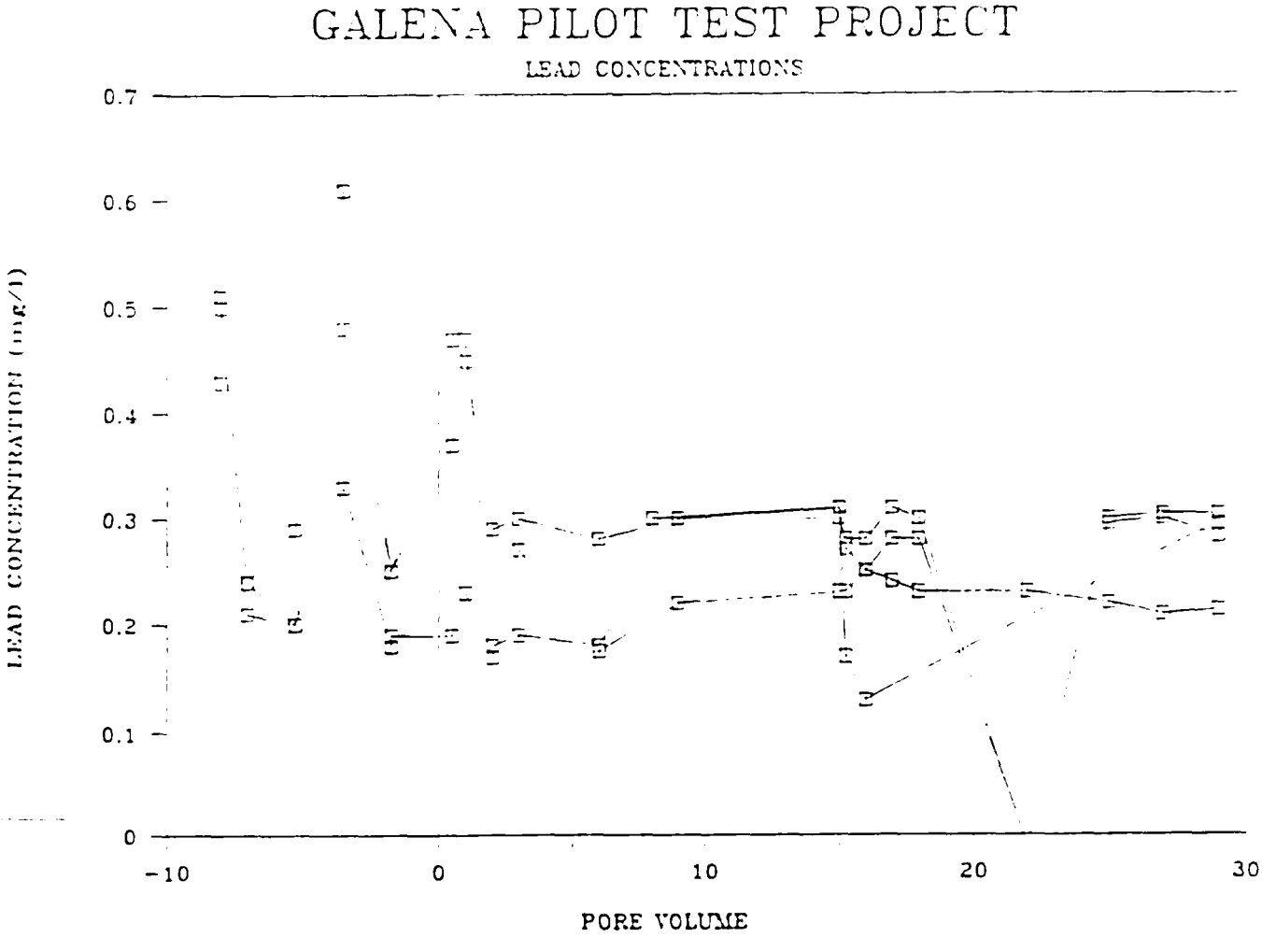
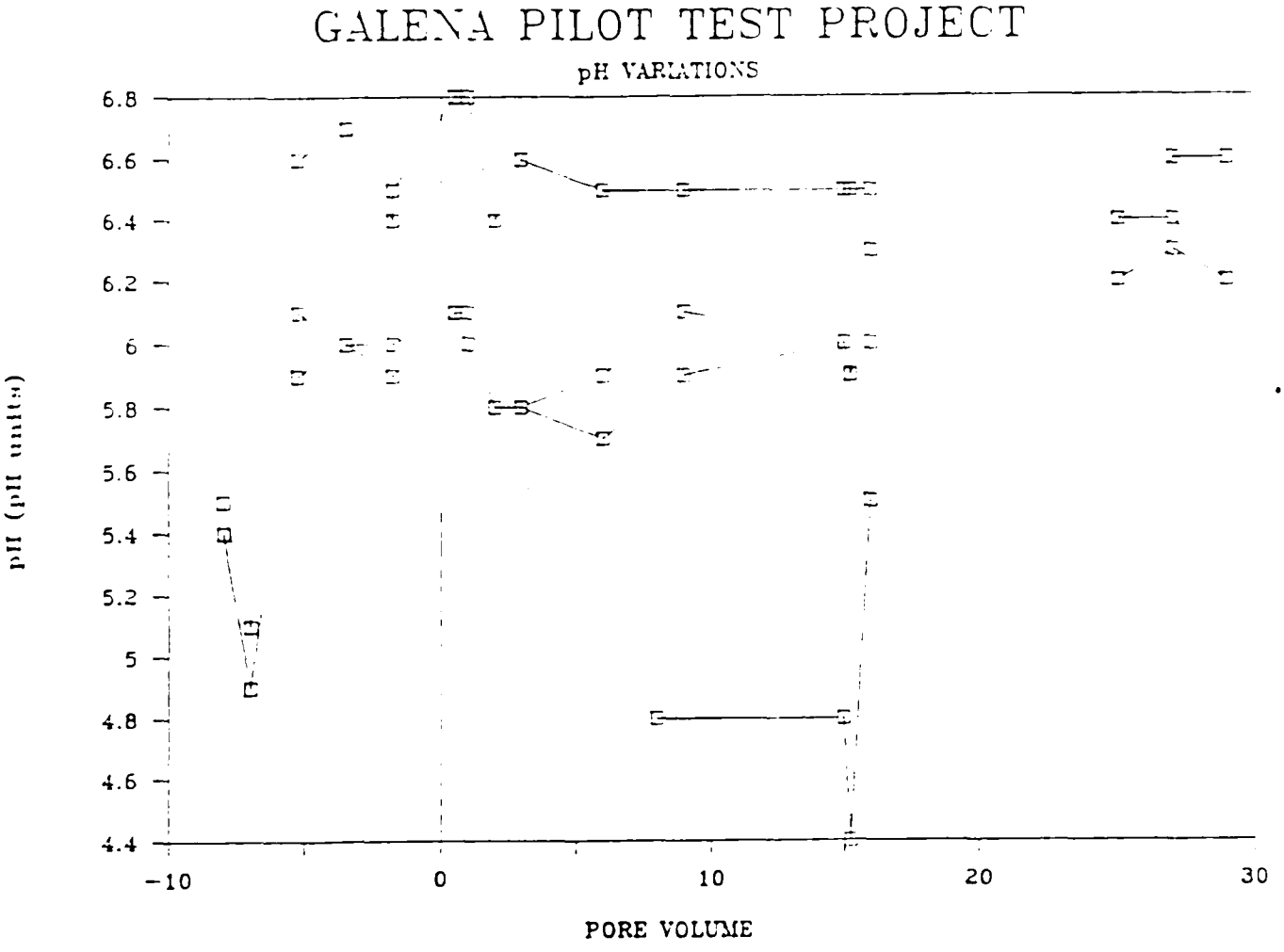


Figure 3.3 - Flow-Through Leach Results

pH IN TANKS 1-3



6.2 throughout the remaining 35 or so pore volumes. (Most of the apparent variation in pH is accounted for by the changes in pH of the water in the input water (Figure 3.3).)

Furthermore, in all three tanks, the pH rises into the range at which pH may control the solubility of the three trace metals. This conclusion is supported by the trends in the dissolved metals values: by pore volume 2 of the first cycle cadmium, lead and zinc values are at or near the average values in the Pond 524 waters and well within the range observed in all previous investigations. That is, little or no additional metal is being solubilized under the test conditions beyond the first few pore volumes.

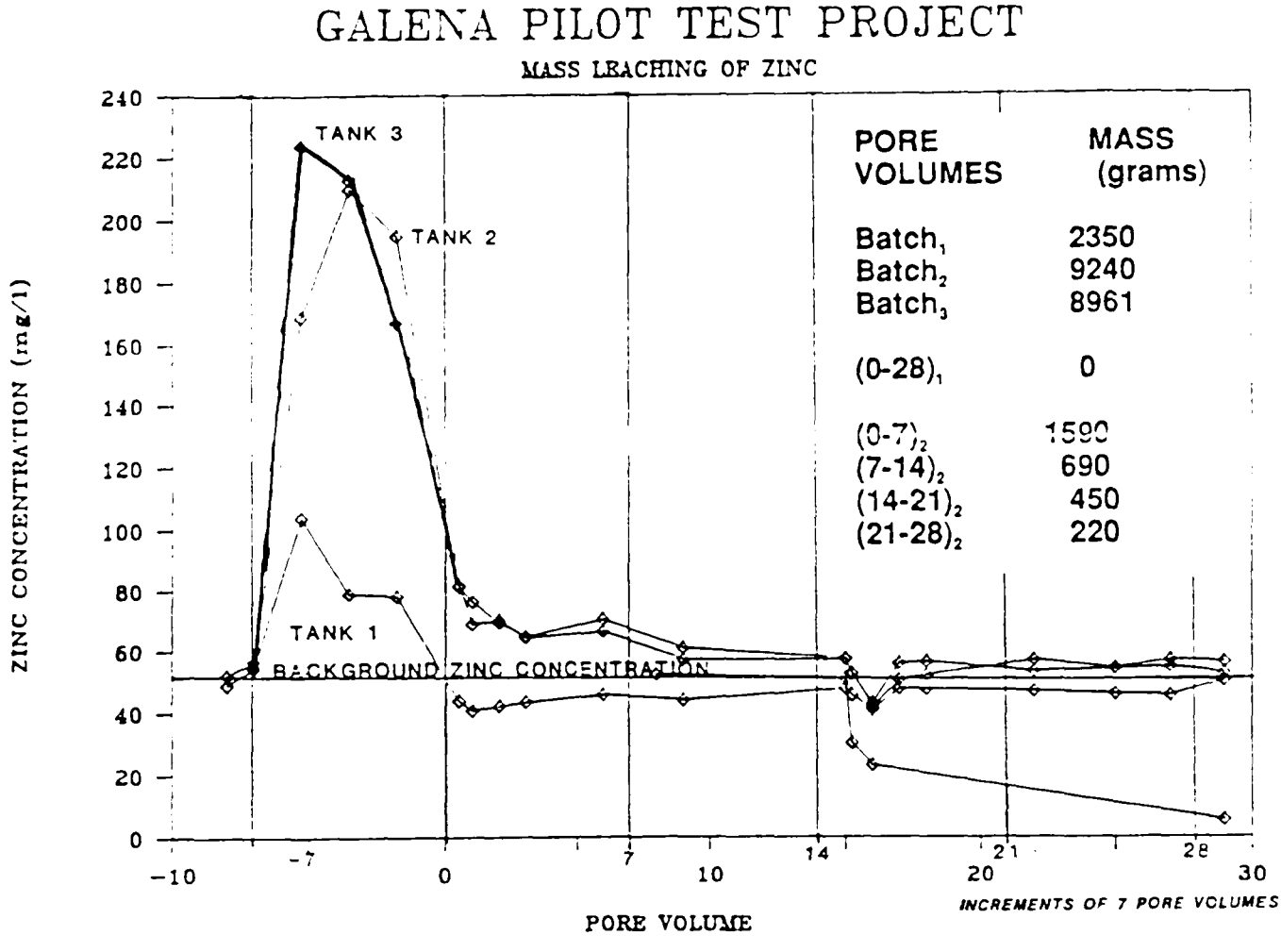
Based on the pH, TDS and conductivity trends, it seems that the major-element chemistry does not differ significantly after initial phases of reaction under these experimental conditions between leaching of calcareous or siliceous waste rock mixed with chat. The similarities in long-term leaching are consistent with the expectation that, after initial reaction on available surfaces, leaching in a flow-through system is limited on the basis of surface area (and related diffusion considerations), which for the two styles of waste rock are very similar.

For all three experiments, the fresh-face phenomenon can be observed: the solution chemistry changes most rapidly for all parameters during the first 24 hours (i.e., during the initial batch test), following which the rate of change in solution chemistry decreases for all parameters. These data, then, are

consistent with the batch test results in indicating that it is prudent to avoid crushing or otherwise increasing surface area and developing fresh mineral faces.

We have also considered the batch and flow-through results in terms of the mass of leachable metals on the basis of an equivalent-pore-volume extraction, to test the signficance of flow rate in determining the results. Figure 3.4 shows the data for leaching of zinc in the three flow-through tanks. Also highlighted is the input zinc concentration throughout the test, represented by the zinc concentration in the header tank water. Based on a flow rate of 2 gallons per minute, the 24-hour batch test represents the equivalent of approximately 7 pore volumes of flow. Therefore, we have numerically integrated the areas under the three zinc curves but above the baseline curve in 7-pore-volume increments. As can be seen, the mass of zinc that can be extracted by an equivalent amount of water decreases steadily (in fact at the same rate as the concentrations) throughout the experiment. This shows that the decrease in concentration seen in Figures 3.2A to 3.2C is related to the actual leachability of the waste materials in the site ground waters and is not an artifact of the flow rate that was used.

Figure 3.4 Mass Leaching of Zinc



With respect to evaluating the Additional Alternative, the most significant result of flow-through leaching testing is that placing of the waste rock below the water table can be expected to have very little long-term impact on present water quality. What limited reactions occur seem to happen as a result of crushing and fresh-face phenomena in the very early stages of disposal. In fact, based on these experiments, disposal below the water table without treatment (i.e., mixing or crushing) would likely lead to essentially no long-term incremental increase in concentration of cadmium, lead and zinc. However, if waste materials on the surface are a major source of solutes in the existing water quality due to variably saturated leaching above the water table (see ABC, 1988a for variably saturated leach test data), disposal below the water table would have the long-term effect of decreasing both the concentration and the flux of metals in the groundwater system. (For an statement of the view that the surface wastes are not necessarily a significant source, see Anginc, 1988 and Section 3.1.2 above.)

3.4 COMPARISON OF TEST RESULTS WITH AMBIENT WATER QUALITY

Table 3.6 compares the results of the pilot tests to previously published ranges of ambient water quality data for the immediate vicinity of Galena. This table summarizes the data of Spruill (1984), the Phase I Remedial Investigation, and the PRPs' 1988

Table 3.6 Comparison of Pilot Leach Data to Reported Ambient Water Quality Data

GALENA PILOT TEST - ABC 1091C DATE UPDATED: 27-Jun-89

WATER QUALITY DATA FROM SPRUILL, 1984 - USGS OF-84-439

MINE	LOCATION	DATE	umho/cm COND	su pH	ppm DO	mg/l SO4	Cd	Pb	Zn
23	34-25E-14DAC	11-Aug-81	411	6.7		140	0.22	1.9	36
		15-Mar-82	367	6.2		140	0.2	1.4	42.3
		15-Mar-82	NA	6.2					
		15-Mar-82	360	6.1		140	0.23	0.9	44
24	34-25E-12DDD	12-Sep-81	696	5.2	0.2	350	0.04	0.01	72
		19-Nov-81	415	4.2		190	0.001	ND	0.32
28	34-25E-13AAB	12-Sep-81	359	3.7	0.6	140	0.34	0.25	40
29	34-25E-13AAA	12-Aug-81	353	3.9	1.2	150	0.34	0.24	39
30	34-25E-13DCA	13-Aug-81	245	3.9	5.4	98	0.32	0.24	35
31	34-25E-14CAC	14-Aug-81	608	4.7		300	0.02	0.01	60
		16-Mar-82	678	4.7	5.2	290	0.15	0.38	79
		16-Mar-82	NA	4.7	0.5				
		16-Mar-82	NA	4.7	0.2				
		16-Mar-82	NA	4.7	0.2				
		16-Mar-82	665	4.7	0.1	290	0.15	0.24	79
33	34-25E-14CBD	14-Aug-81	459	3.6	1.8	200	0.05	0.06	31
SUMMARIES		Maximum	696	6.7	5.4	350	0.34	1.9	79
		Minimum	245	3.6	0.1	98	0.001	-0.01	31
PILOT TEST PONDS		Maximum	540	7.3	11	183	0.13	3.9	51
		Minimum	128	3.3	0.6	23	-0.01	-0.01	1.1
PILOT BATCH TEST 1-6		Maximum	510	6.2	1.4	318	0.2	1.1	64
		Minimum	490	5.2	0.4	240	0.12	0.4	35
1988 BATCH (DI)		As Rec'v'd	32	5.2		-10	-0.01	0.39	1.2
		-1"	199	6.3		28	0.09	3.67	23
		Crushed comp	94	6		71	-0.01	2.46	7.9
1988 SATURATED COLUMN TEST (METHOD2)		DAY 2	183	6.5		64	0.07	2.42	12.4
		DAY 5	293	6.58		107	0.11	2.52	25
		DAY 9	391	6.39		135	0.09	2.23	32
		DAY 15	393	6.7		125	-0.01	0.26	23
		DAY 28	268	6.74		84	-0.01	0.06	0.46

NOTE: "-" INDICATES "LESS THAN" THE DETECTION LIMIT SHOWN

laboratory-scale tests (ABC, 1988a), as well as the new results from this pilot testing.

As can be seen from Table 3.6, the only data from the pilot leach tests that fall outside the previously published range of chemical parameters for waters in flooded mines in the Galena area are the 24-hour batch test results from the three tanks. (All of the 55-gallon drum tests (Batch Tests 1-15) fall within the previously reported range.) In the tank batch tests, values for zinc and sulfate fall outside the published range by a factor of about 2.5. However, the initial (Pore Volume 0.5) data from those tanks in flow mode are back to the upper limit of the Spruill (1984) data. By Pore Volume 2 of the first cycle, the values are all well within the previously reported range, and the remainder of the pilot testing flow-through data indicate that the solute concentrations are decreasing with time and ground water flux toward and to the background values under ambient conditions.

Note, too, that the differences in chemistry that result from batch tests 1-15 are similar to or less than the changes in water quality observed in ABC (1988a). As discussed both above and in ABC (1988a), most of the leaching in the batch-mode tests can be ascribed to surface-area and mixing effects. The batch-test results are expected to overestimate, probably substantially, the concentrations of metals and other dissolved constituents to be expected due to long-term leaching of waste rock and chat that

might be disposed of in major ground water ponds in the Galena area.

3.5 HYDRAULIC CONDUCTIVITY OF FLOW-THROUGH TEST MATERIALS

The test materials were sufficiently coarse grained that, as expected, no discernible darwdown was observed during the actual flow-through tests. Figures 3.5 and 3.6 show drawdown versus time plots developed from measurements made during the draining of the flow-through test tanks. Figure 3.5 is the set of plots for the constant flow drawdown test conducted after the initial batch tests; Figure 3.6 is the set of plots for the step drawdown tests conducted at the end of the entire flow-through test program.

The data have been evaluated in the standard manner, using a formulation of Darcy's law. The actual calculations are presented in Appendix D. Both types of test allow rapid estimates of hydraulic conductivity of the test materials. For all tanks, the tests indicate a hydraulic conductivity in the range of 3 E-1 cm/s to 6 E-1 cm/s. For Tanks 2 and 3, the mixtures of siliceous waste rock and chat, the tanks drained in about half the time needed to drain Tank 1, suggesting that the calcareous waste rock - chat mixture is slightly less permeable than the siliceous waste rock/ chat mixture. These differences correspond to the Project Engineer's observation that the calcareous waste rock was somewhat less coarse grained, on average, than was the siliceous waste

Figure 3.4 - Constant Flow Drawdown Tests

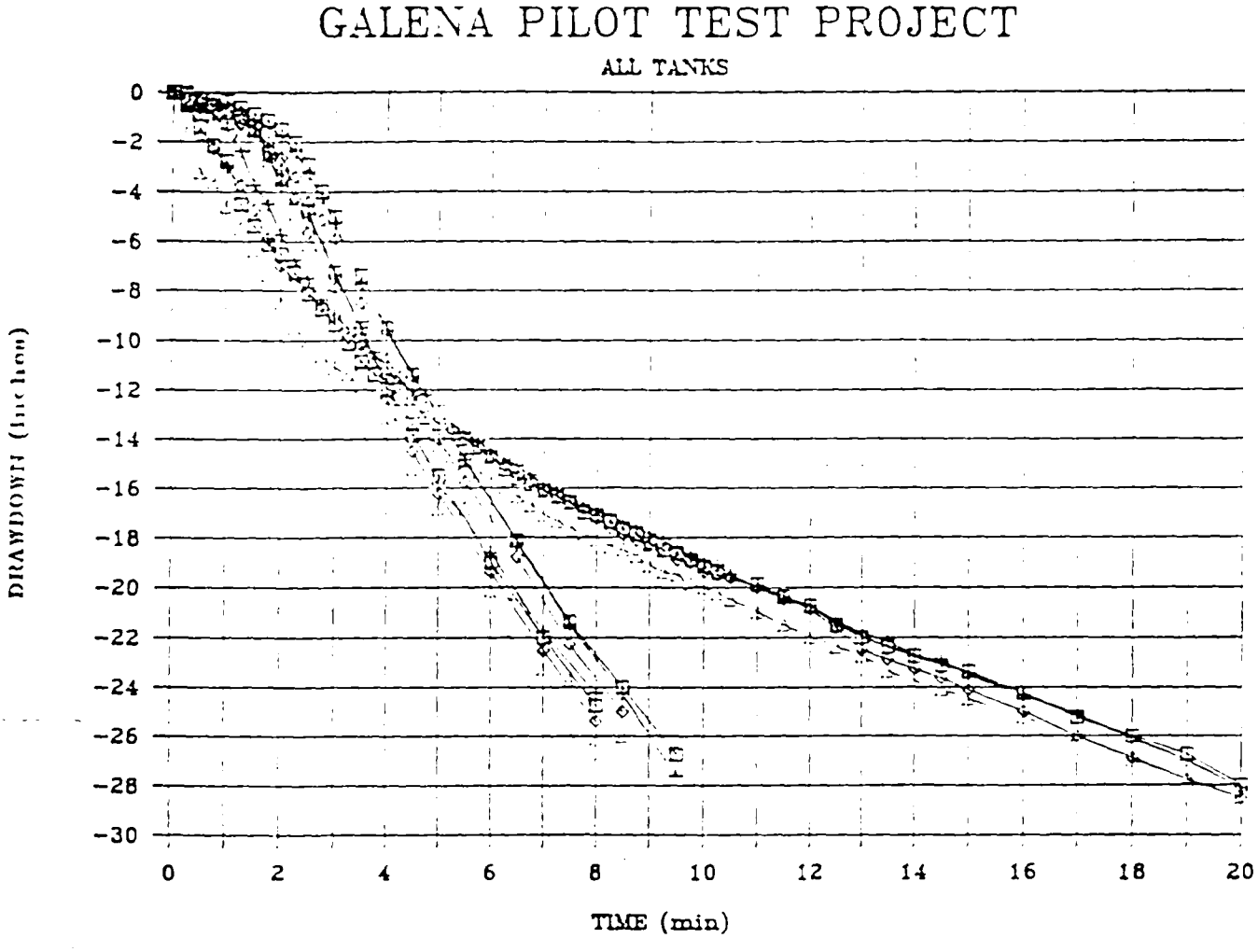
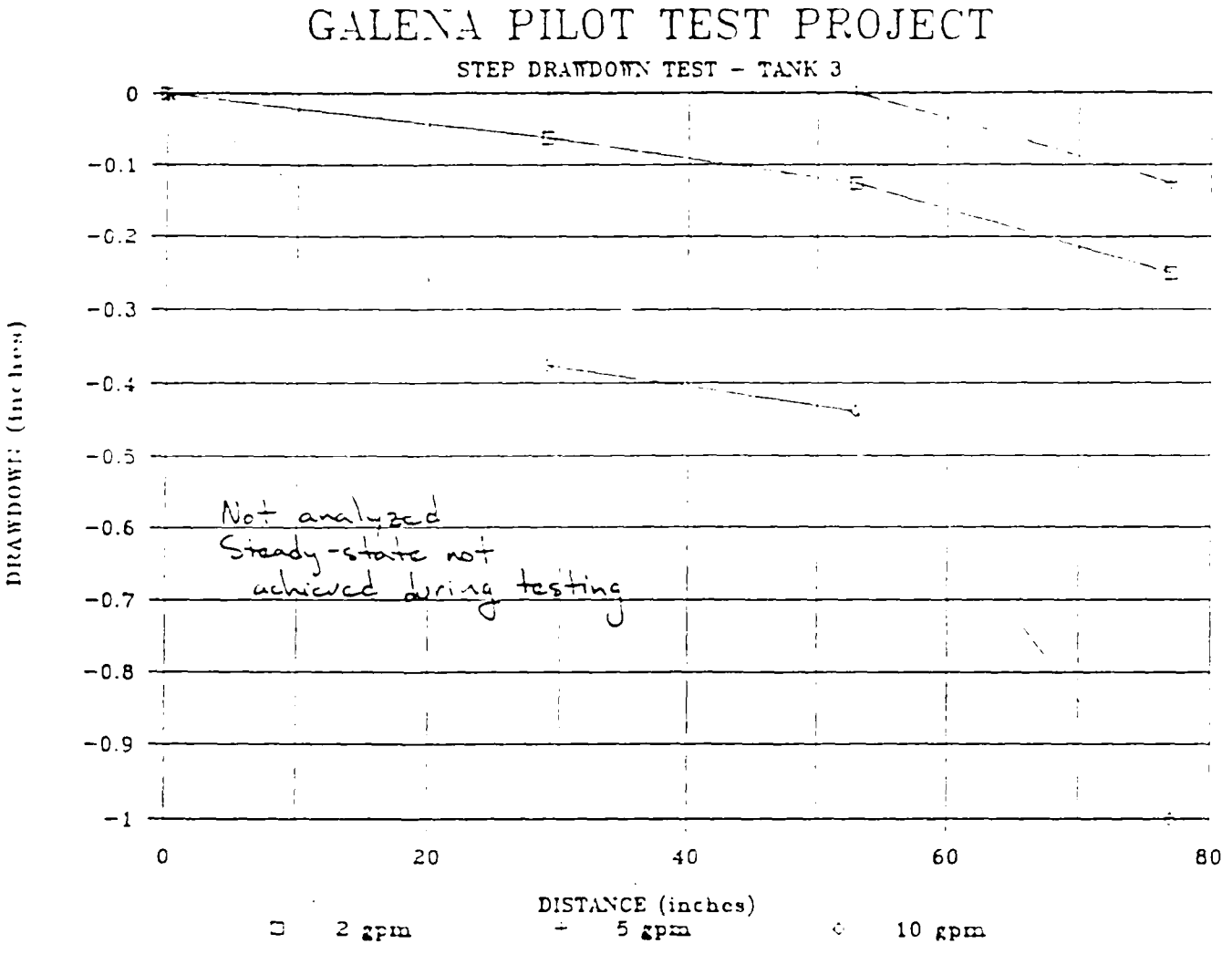


Figure 3.5 - Step Drawdown Tests



rock. (The drawdown curves for Tanks 2 and 3, the duplicate tests with siliceous waste rock, are indistinguishable, indicating uniform mixing between the two test charges.) Note particularly that all values are in the same order as the hydraulic conductivities for clean sand to gravel (Freeze and Cherry, 1979), as would be expected for the grain sizes observed (i.e., chat roughly equivalent to sand, and plus 2 inch waste rock roughly equivalent to gravel).

Both sets of values are much higher than the estimates presented in the RI, which were near 1 E-4 for intact country rock. If these tank tests were considered significant, they would indicate that the flow through actually emplaced backfilled material would be controlled by the hydraulic conductivity of the intact country rock, not by the hydraulic conductivity of the backfilled material itself. This indicates that the backfilling will have no discernible effect on the effective hydraulic conductivity of the lateral flow system, and therefore on mass flux of water.

Note, however, that no particular significance is attached to the absolute values of these tests results, because they apply to the intimately mixed waste rock and chat used in the tanks. As discussed in Section 2.3 above, there is no technical reason or plan to require such intimate mixing as part of an Additional Alternative. Therefore, these data, which were required by the Work Plan and the Field Operations Plan are included for completeness of the technical presentation only.

3.6 SUMMARY OF RESULTS

The results obtained from this testing program are both consistent and fundamentally simple. In summary, they are as follows:

1. It is possible to leach metals, particularly zinc, from samples of the Galena Subsite's waste rock and chat, at least initially, as was observed in ABC (1988a).

2. The amount and rate of leaching depend on the grain size of the material being leached, the amount of mixing of materials, and to a lesser extent on the presence of oxygen.

3. The rate at which leaching occurs does not appear to be particularly sensitive to the waste-rock matrix, based on results from the leaching of calcareous and siliceous waste rock mixed with chat.

4. The rate at which leaching occurs decreases rapidly with time in the flow-through environment. The corollary of this is that the less the disturbance of the waste material that takes place, the lower the rate of metals dissolution to be expected.

After a period of time (apparently a very short period), it appears that all the materials are similar in their behavior. The trends in the data are clear. After the initial batch leaching event, metal concentrations of leachate fall rapidly towards very small values, at or even

apparently below the background values for Pond 524 and substantially within the range of values observed by Spruill (1984), CH2M Hill (1987), and ABC (1988a). Similarly, incremental mass loading also decreases quickly to indistinguishable levels. Simply put, after a short period of re-equilibration, the waste rock and chat disposed of below the water table in Galena-area ground waters do not appear likely to provide significant dissolved metals (or other solute) loading to the local ground waters and, ultimately, to any surface water drainage.

5. The hydraulic conductivity of the mixed waste rock and chat used in the flow-through tests is approximately 3 E-1 cm/s. This value, which is much greater than the estimates of approximately 1 E-4 cm/s for intact rock presented in the RI, is if very limited physical signficance, because there is no plan to mix waste rock and chat as part of Additional Alternative (see Section 2.3 above). If the hydraulic conductivity were considered significant, it would suggest that the flow through the total system will be controlled entirely by the permeability of the country rock. Thus, the permeability of the emplaced material is not likely to have any significant effect on the flow system.

4.0 WATER QUALITY IMPACTS

The available data from previous work and the new field characterization and pilot leaching data allow an evaluation of the likely incremental impact of the Additional Alternative. Under current conditions, infiltrating water may move through the waste rock and chat on the surface, leaching some metals from those materials as it recharges the ground water of the shallow flow system. The shallow ground water system discharges to the surface streams in the area, potentially contributing to chemical loading of those streams. Based on the data of this investigation, it is expected that there would be no discernible impact on water quality if waste rock and chat were disposed of in subsidence features of the Galena Subsite. Additionally, the data indicate that there would be no discernible difference in expected ground water quality between the Additional Alternative and the current (i.e., no action) situation.

4.1 FLOW CONCEPT

The ground water conditions on the site have been extensively investigated from 1911 (Bailey, 1911) to the present (EPA, 1986; Spruill, 1984; Hutchison, Brown, and Smith, 1986; Angino, 1988; ABC, 1988a). All investigators agree that the ground water conceptual model for the mineralized area comprises essentially the following components:

1. Surface water infiltrates into the near surface environment, either directly from precipitation or by capture from streams.

2. The water charges the near-surface aquifer which is made up of Mississippian age limestone and chert, which in the Galena area was also the orebody. In the subsite area, this water-bearing unit is about 340 feet thick on average and is of moderate permeability except in the mineralized areas, where the permeability is locally high.

3. As oxygenated recharge water percolates into the mineralized areas and through the surface waste rock and chat, this water reacts with the pyritic sulfide mineralization, oxidizing the sulfides. As a result, pH decreases (unless the mineralization has sufficient buffer capacity to offset the acidity) and metals, sulfate and other species are mobilized.

4. Water from the near surface aquifer flows into the local streams, carrying with it any metals and other dissolved species that have been mobilized.

4.2 THE ADDITIONAL ALTERNATIVE

The Additional Alternative proposed by CH2M Hill involves the placement of the surface materials (waste rock and low-zinc chat) in the existing subsidence and other depressions in and around Galena. This will have the effect of placing a considerable amount of the materials currently on the surface below the water table.

Based on all the testing done in this program and the 1988 laboratory program (ABC, 1988a), the lowest experimental concentrations of metals are provided by saturated leaching of waste materials. After only a few pore volumes of flow, it appears that the fresh faces provided by crushing the waste materials in the pilot handling procedures have ceased to contribute significant metals or other dissolved species to the groundwater, and cadmium, lead, and zinc concentrations are all controlled at low values, characteristic of the baseline range of water quality (Cd near .01 mg/l; lead near .5 mg/l; zinc near 50 mg/l; see Table 3.3 above). These values indicate that there is little or no discernible incremental impact in the long term (or even in the short term beyond an initial leaching that probably is related to materials-handling issues) on water quality to be expected from saturated disposal of these materials.

The data from the pilot tests are fully consistent with the data from the laboratory-scale saturated leaching experiments

previously reported by the PRPs. In those tests, concentrations of dissolved metals had returned to or near detection by day 28 of the Method 2 experiments (ABC, 1988a). (Because of the use of pH-adjusted distilled water as the lixiviant in the 1988 experiments, the appropriate measure for comparison in the current results is the incremental change in metals from the baseline to post-test values, not the absolute value of the final leachate concentration.)

Note that even if all of the waste rock and chat cannot be disposed of below the water table (the CH2M Hill proposal calls for only the coarse-grained fraction of the waste rock and the low-zinc chat to be disposed of in the saturated zone), the source-term will be reduced over the current source-term by whatever proportion can be disposed in fully saturated conditions. Field evaluations reported by Andes (1988b) indicate that in EPA Zones 1-8, there is approximately 810,000 cubic yards of saturated disposal space, exclusive of the volume of some 377 saturated mine shafts. The readily accessible saturated volume calculated by Andes amounts to about 55% of the combined waste-rock and chat volume in the Galena Subsite. Thus, without any treatment or even use of mine shafts, disposal of waste materials to saturated voids may be expected to reduce more than half of the current physical source-term to de minimus incremental concentrations of potential leachate (where the baseline (i.e., ambient) water chemistry is considered to be a de minimus level, given the natural processes in the system). As pointed out by Andes, there is more than

enough space available in total mine voids (both saturated and unsaturated) to accomodate the total volume of waste rock plus chat, and detailed engineering design should allow handling procedures that could meet the requirements of the CH2M Hill Additional Alternative.

4.3 EVALUATION OF FUTURE WATER QUALITY UNDER THE ADDITIONAL ALTERNATIVE

The long-term water quality of the Galena Subsite area depends on factors other than the handling of waste rock and chat that are now located on the ground surface. Simple mass-balance calculations (including pH considerations) show that one cannot develop a subsurface water composition like that of the shallow mine waters of the Galena area by mixing the long-term leachate from the flow-through tests with local groundwaters that appear to be unaffected by the mining activities. To illustrate this simply, there is no combination of two simple solutions with pH 6 (Tanks 1-3) and 6.7 (Spruill's Site 115) that will produce a water with pH 4.4 (e.g., Pond 524). Similarly, to produce a water with 40 to 50 mg/l zinc (assume 45 mg/l for the purposes of computation), as seen in the Pond 524, from a chat/waste-rock leachate (Tank 1-3 long-term concentrations of approximately 50 mg/l zinc) and groundwater from site 115 (0.40 mg/l zinc) requires that the Pond 524 water be approximately 90% leachate and only 10% groundwater; not only is this physically unreasonable for a

flow-through ground water system given the climate and geology of the site, but it also is not reproducible for other species. The most fundamental conclusion of the flow-through tests is that long-term water quality will be essentially indistinguishable from baseline range of ambient water quality.

Based on the totality of the leaching data of both this project and the 1988 PRP experimental program and a review of the mine-water quality, it seems likely that the metals content of leachate from the waste rock and the chat today - some 75 to 100 years after the end of mining - will not be discernibly different than the water quality that already exists in the shallow ground water system (and that is due in large part to natural processes (Angino, 1988). Apparently, the contribution of metals to the water in the mine pools from surface waste rock and chat is probably a small proportion of the total metals in solution (ABC, 1988a). Furthermore, the new pilot tests show that no significant incremental increase in concentrations is to be expected if waste rock and chat were to be disposed of below the water table under the Additional Alternative.

As has been proposed elsewhere (e.g., Spruill, 1984; Angino, 1988), the chemistry of the mine water is probably related primarily to the reaction of oxidizing water at and near the water table with residual mineralization in the mine voids and the mineralized country rock. In addition, to the extent that the column leaching experiments of the PRPs 1988 laboratory program

represented useful simulations of leaching above the water table, similar solutions can be expected to arise from the movement of natural infiltration through vadose-zone rocks that contain similar mineralogy. That is, natural recharge through mineralized (even sub-ore-grade) rock would be expected to provide metals to a groundwater mixing zone, such as is provided by the drowned mine voids and throughout the flow system to the streams (ABC, 1988a). This is the essence of the common-cause hypothesis discussed in Section 3.1.2 above.

Because the incremental source-term metals are low to indiscernible in the long-term pilot-scale leaching, it is clear that disposal below the water table is superior to disposal above the water table, all else being equal (see ABC, 1988a). Any saturated placement (without treatment or materials handling that increases surface area) will improve the ultimate water quality to the extent that the current, variably saturated waste materials on the surface are an assumed source-term for current ground water conditions.

Two conditions to this conclusion must be stated. First, as discussed in Section 3.1.2, it is not clear that surficial mine wastes are, in fact, significant contributors to the current ground water conditions. The lack of spatial correlation between presence of mining wastes at the surface and water quality (particlarly pH and metals concentrations) in adjacent ground water argues against a clear causal connection. Repeating the

conclusion of arguments presented above, the mining wastes and the water quality are best explained causally in terms of a common cause relationship of the sort described by Reichenbach (1956).

Second, it is most likely that there will be no identifiable effect on water quality from disposing of the surficial wastes to the saturated zone. This can be seen from two perspectives. It can be shown that the 800,000 cubic yards of saturated disposal volume is much less than 1% of the total saturated volume of the shallow aquifer in the 2500 acres of mineralized ground. Therefore, on simple mass-balance considerations, it is clear that the effect on the total system will be small. Even more importantly, based on the leaching data of this report, by the time approximately 2 pore volumes of ground water have reacted with the test materials, concentrations of dissolved species have returned to the range of baseline conditions. That is, no effect due to the Additional Alternative is or would be expected to be discernible in comparison with the range of observed ambient conditions.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 OBJECTIVE OF THE STUDY

The purpose of the pilot leach study was to evaluate the effects on water quality of moving waste rock and low-zinc chat to saturated mine voids in the Galena subsite area. A secondary objective was to evaluate the leaching behavior of the Galena mine waste materials in local ground water.

5.2 CONCLUSIONS

The conclusions of the PRP studies are as follows:

1. There is not a clear causal connection between mining wastes at the surface and shallow water quality. In particular, the mining related materials that remain on the surface at the Galena Subsite apparently provide a very small contribution to the overall metal flux to the ground water or streams in the area (ABC, 1988a) and there is extensive natural mineralization that affects the ambient ground water quality (Spruill, 1984; Angino, 1988).

2. The Additional Alternative, if carried forward, is estimated to halve the total mass flux of dissolved metals from this source by halving the amount of waste material that exists above the water table.

3. The net effect on water quality in the shallow ground water system and the local streams is expected to be indiscernible.

4. The groundwater flow system is not expected to be modified by the Additional Alternative.

5.3 RECOMMENDATIONS

Perhaps the most important finding of this study is that when the tested waste materials are submerged, there is essentially no further liberation of metals from the rock after an initial leaching that may reflect materials-handling issues. This suggests that to the extent that the waste rock and chat currently constitute a source, it could be mitigated effectively by relocating the waste materials in the submerged mine openings, which is what the Additional Alternative contemplates.

Alternatively, the current data are also consistent with a proposal for no action. Because there likely will be no discernible effect on water quality from the Additional Alternative and because the surfical waste materials are not

demonstrably the cause of the ambient water quality, there is no clear benefit (but very substantial costs) involved in moving the materials. If decision-making is to be based on water-quality considerations, then avoiding the short-term impacts that will likely occur when the materials are handled (and inevitably crushed) suggests that leaving the surficial materials in place would be appropriate with respect to both long-term and short-term water-quality impacts.

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